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**PHYSICAL CAPACITY EVALUATION AND RECONDITIONING
OF
PATIENTS WITH CHRONIC PAIN**

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Thanks Norm, thanks Shana...

Common reasons to prescribe exercise for back patients

to decrease pain

to strengthen weak muscles

to decrease mechanical stress to spinal structures

to improve fitness level to prevent injury

to stabilize hypermobile segments

to improve posture

to improve mobility

when all else fails...

Jackson RP & Brown MD, 1983

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LIST OF ABBREVIATIONS

BPM : beats per minute

CRE : cardiorespiratory endurance

HR : heart rate

PA : physical activity

PWC : physical working capacity

PWC_n : physical working capacity at a heart rate of n beats per minute

PWC_n/kg : physical working capacity at a heart rate of n beats per minute
per kg of body weight

RCT: randomized clinical trial

RPE : rate of perceived exertion

RPE_{65%} : rate of perceived exertion at an exertion intensity corresponding
to 65% of HR-reserve

VO₂ : oxygen uptake

VO_{2max} : maximal oxygen uptake

INTRODUCTION

Pain is generally defined as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage' ¹⁶¹. Traditionally, only time is considered in distinguishing acute from chronic pain. Three and six months are the two arbitrary pain durations most commonly cited to denote chronic pain ¹⁶¹. However, chronic pain is also described as pain that 'extends beyond the expected period of healing'. As recalled by Turk and Okifuji, chronic pain is generally elicited by an injury but is perpetuated by factors that are distinct from the original cause ¹⁶¹. From a clinical perspective, biological, psychological as well as social factors have been recognized to play important roles in the development and perpetuation of chronic pain. We shall briefly introduce them, as they are all relevant to the subject of this thesis.

a. The neurobiology of chronic pain.

Normally, in the nociceptive system, a steady state is maintained between injury and pain. However, temporary changes in nociceptive input or in the environment can result in variations in the quality and quantity of pain sensation produced by a given noxious stimulus. These adaptative responses (e.g. peripheral and central sensitization) are also temporary as the system usually restores the normal physiological balance between injury and pain. Nevertheless, long-lasting and/or very intense noxious stimuli or the removal of normal somatosensory input (deafferentation), could distort the nociceptive system to such an extent that the normal balance between injury and pain would be lost. These abnormal plastic changes in the nociceptive system as a consequence of past injury generate abnormal sensations and behaviors.

However, patients with a seemingly identical history of damage may or may not complain of pain. Thus, the development of these abnormal states may involve genetic, cognitive and emotional determinants that have to be identified.

b. Emotional and cognitive processes and the experience of chronic pain.

Unconscious (without subject awareness) affective and cognitive (e.g. beliefs, learned responses...) processes increase or decrease the perception of pain. If threatening illness or injury information has been given to a subject, pain-related fear may develop and, ultimately, the subject may become hypervigilant and present with an avoidance behavior in general and towards physical activity in particular. Vlaeyen et al.¹⁷² have underlined that fear of re-injury and hypervigilance may become more disabling than pain itself as such behaviors may lead to depression and disuse. Such emotional and cognitive processes will be discussed in this thesis as we find that they play major roles in the onset and perpetuation of chronic pain. Moreover, they may also interfere significantly in physical capacity assessment.

c. Social and cultural influences.

Social learning influences the meaning and significance ascribed to pain and the way the patient communicates his experience of pain. It also affects healthcare seeking and response to treatment. A patient's family and social environment may also play a complex and intricate role in the perpetuation of pain and disability. For instance, chronic pain may affect male and female patients differently in terms of physical activity level and fitness. Such a rather surprising finding will be more extensively described and commented further in the present manuscript, as it constitutes one of its significant contributions.

These three factors are functionally interdependent and constitute the main components of a coherent new 'biopsychosocial' model of chronic pain and disability. Such a model represents an interesting and valuable alternative to the traditional 'medical' or 'disease' model for the management of pain that has major limitations making it of very little value in daily clinical practice. An outline of this new 'biopsychosocial' model with emphasis on the psychological and social factors is presented (Fig. 1).

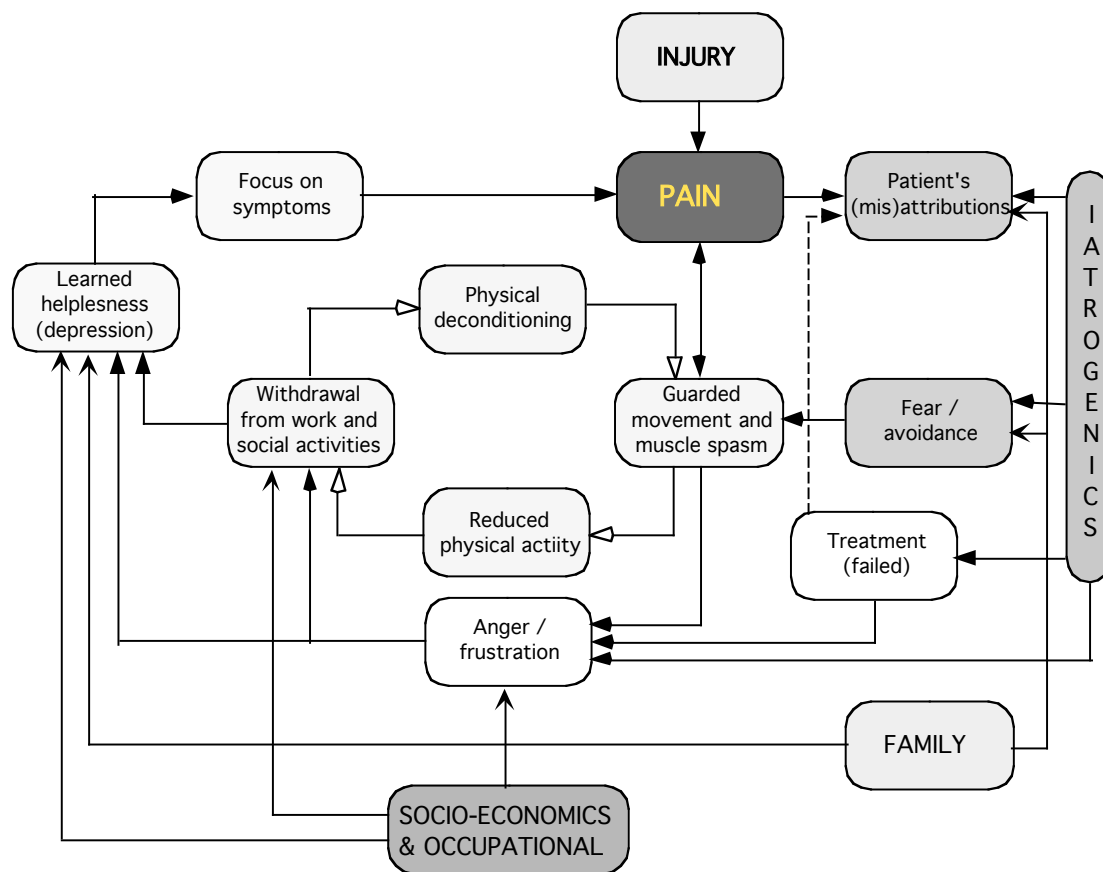


Figure 1. The 'biopsychosocial' model adapted from Main and Spanswick⁹⁰. 'Reduced physical activity' and 'physical deconditioning' are at the core of the overall process leading the injured patient towards chronic pain and disability.

The major aim of this thesis is to assess the validity of this model. Therefore, physical fitness and related terms must first be defined and the issues of validity and reliability of physical tests as implemented in patients with pain will be addressed to help clarify the confounding reports that can be found in the literature on the topic.

The main questions our research work was intended to address were as follows:

- How can physical fitness and related concepts be defined in the context of chronic pain?
- What do maximal physical tests in patients with chronic pain really measure?
- How is it possible to evaluate cardiorespiratory endurance (CRE) in patients with chronic pain?
- Which test is the best to evaluate fitness in patients with chronic pain?
- Are patients with chronic pain unfit and less active?
- Is physical reconditioning possible and helpful in patients with chronic pain?
- How do physical activity and pain relate in patients with chronic pain?
- How do patients with chronic pain perceive physical exertion; could a distortion in the perception of physical exertion play a role in the onset and/or the perpetuation of their condition?

In the General Discussion (chapter 3), we will readdress these issues point by point in the light of our research results that will be presented in

chapter 2 (Main results) and discuss them with the results obtained by other investigators. But before to start and in order to put our findings in the right perspective, we will (1) briefly review the literature on the epidemiology and etiology of back pain, as it constitutes by far the most frequent of chronic pain syndromes, and, (2) evaluate the earlier results obtained in the field of physical testing in patients with chronic pain with special attention to their validity and reliability.

CHAPTER 1: EARLIEST FINDINGS FROM THE LITERATURE ON CHRONIC BACK PAIN SYNDROMES

1.1. EPIDEMIOLOGY OF BACK PAIN

The lifetime prevalence of chronic pain is very high, with males and females being more or less equally affected ^{5, 44}. In industrialized countries most individuals will experience a significant low back pain episode at some time in their life ^{48, 98, 150}. Some authors have even proposed that low back pain could be considered as a condition within the range of normal variation ¹⁴⁴. In general, the first back pain episode occurs relatively early in life, most subjects being first affected between 40 and 50 years of age ^{18, 150, 174}. Most patients recover function and comfort within 3 months of the onset of low back pain ^{16, 33, 39, 139, 174}, although, 30 to 70% suffer from recurrent low back pain ¹²⁸ and 5 to 10% develop persistent and chronic back pain ^{36, 44, 45, 115, 128}. Moreover, the prevalence of low back pain is increasing rapidly¹⁷⁵. For instance, the US National Center for Health statistics show that between 1971 and 1981, the number of people with disabling chronic or recurrent back pain increased by 168% while the total US population increased only 12.5% ⁵⁷.

Patients with chronic pain often present with significant functional impairment and, consequently, an inability to engage in many activities of daily life including work ⁴⁰. Moreover, low back pain is the most frequent cause of physical activity limitation in adults under 45 years of age ¹⁰⁵.

In the USA, more than 50 million individuals see their ability to work affected by pain ^{5, 167}. Among those who are off work for a period longer than six months, only about 50% will ever return to work ^{44, 46, 150, 180}.

Consequently the direct and indirect economic costs of low back pain have been estimated to be between \$16 and \$50 billion per year in the USA ^{128, 180}. Patients with recurrent or chronic low back pain generate 75 to 90% of the total costs of back pain ¹¹⁴.

The epidemiology of back pain is equally worrying in Europe ^{15, 18, 37, 43, 166, 175}. Waddell has called disability related to back pain a recent exponentially rising Western epidemic ¹⁷⁴. European and USA health care systems are quite different, yet neither of them succeeds in limiting the back pain epidemic. Waddell points-out that, despite the availability of sophisticated expensive treatment modalities, there is growing dissatisfaction with the health care for back pain on both sides of the Atlantic, which may indicate that the traditional medical model is inappropriate for back pain management ¹⁷⁵. The fact that more and more back pain patients are seeking expensive alternative treatment modalities also illustrates the failure of the traditional medical approach.

In summary, the lifetime prevalence of chronic pain is very high and still regularly increasing in industrialized countries. In the early nineties, the total economic cost of back pain has been estimated to be close to \$50 billion per year in the USA. Such numbers underline the failure of the traditional medical approach for back pain management.

1.2. ETIOLOGY OF BACK PAIN; ROLE OF PHYSICAL FACTORS

Given the magnitude of the back pain epidemic, effort must be made to identify its causes and/or predisposing factors. Likewise, understanding why pain becomes recurrent or chronic is important since it may help in developing more efficient prevention and/or treatment strategies. Unfortunately, the proportion of cases where a precise etiological factor can be identified is small ^{114, 128}. It is generally accepted that back pain is related to degenerative changes in the intervertebral joints. However, the correlation between such changes and pain is weak as witnessed by the poor diagnostic value of radiographic imaging in identifying the precise origin of non-radicular back pain ^{17, 47}. Despite the fact that a precise cause can seldom be identified, several prospective studies have attempted to identify the risk factors involved in developing back pain. Among other factors, a relative lack of fitness was often identified, as indicated by low general fitness indices including cardiorespiratory endurance (CRE) ²⁴ and decreased trunk muscle strength ^{16, 18, 151}. However, other factors such as previous history of back pain ¹⁸, psychological or behavioral factors ¹⁹, socio-economic factors ¹⁷³ and smoking ^{11, 18} were also reported. Waddell recently summarized the most important risk factors for developing back pain as: physical factors (heavy lifting, twisting, whole body vibrations...), psychosocial work factors (low job satisfaction, lack of personal control), low physical fitness, and factors related to health behavior (smoking) ¹⁷⁶. It has long been admitted that fitness has a significant protective effect against back injury, especially in the industry ^{4, 24, 73, 74, 134, 151}. This conviction was probably inspired by the often cited prospective study on firefighters by Cady et al. ²⁴ who found fewer subsequent back injuries and a lower compensation costs in the fittest individuals. As a consequence,

until very recently many authors proposed physical reconditioning programs aimed at preventing back pain recurrence and/or increasing the return-to-work rate^{15, 25, 32, 42, 43, 54, 78, 85, 86, 88, 93, 97, 98, 106, 110, 111, 126, 131, 133, 136, 137, 157, 164}.

Numerous cross-sectional studies have found reduced CRE^{22, 105, 164, 183}, trunk muscle strength^{13, 28, 63, 76, 83, 92, 105, 116, 143, 147-149, 153} and/or flexibility^{52, 64, 105, 143} in patients with chronic back pain.

In two different cross-sectional studies comparing patients with severe chronic pain syndromes to healthy controls using a submaximal cycle ergometer test, we found reduced CRE in male patients only^{122, 124}. We will present and discuss the results of those studies further in this manuscript.

Mayer et al. conducted thorough physical capacity evaluations in patients with chronic back pain, and concluded that they presented such a major physical fitness deficit that it was termed a 'deconditioning syndrome'⁹⁶⁻⁹⁸.

In any case, it must be recognized that cross-sectional studies comparing back pain patients to healthy subjects do not determine whether the fitness reduction is the cause of chronic back pain or its consequence.

On the other hand, several studies have suggested that the fitness of back pain patients had to be considered more carefully. As early as 1989, Battie showed that CRE was not predictive of future low back pain in the industry¹¹.

Aerobic capacity of still working back pain patients was found normal by Hurri et al.⁶⁶. Wittink et al. also found aerobic fitness to be normal in female back pain patients and only slightly reduced, but still within the normal range, in male patients¹⁸³. Studies of muscle strength have indicated that back muscle fitness was not predictive of subsequent back pain episodes^{11, 35, 50, 112, 116}. Other studies have questioned the value of physical trunk mobility and strength tests because of the large variability and overlap of performance in back pain subjects and controls^{10, 158}. An

extensive review by Newton and Waddell concluded that there is insufficient scientific evidence to use isokinetic trunk muscle strength testing methods in preemployment screening, routine clinical assessment and medico-legal issues ¹¹⁷. Battie reported a small significant difference in spinal flexibility, but probably with no practical significance, between subjects with and without a history of back pain ¹². Patients with hypermobile backs could be at even more at risk ¹⁶. The relationship between spinal range of motion and disability due to low back pain in workers was found weak or inexistent ¹²⁷. Lahad et al. reviewed 64 studies on the prevention of low back pain published between 1966 and 1983 and concluded that there was insufficient evidence to recommend back and aerobic exercises to prevent low back pain in asymptomatic individuals ⁸⁰. The large number of contradictory observations in the field of physical fitness evaluation in back pain patients led Stieg to argue that physical testing was futile and useless in the assessment of disability in back pain patients ¹⁵². Methodological flaws in many physical fitness assessment methods probably account for the numerous contradictory findings since most of those methods have not been validated in patients with pain. The wide heterogeneity of patients that have been evaluated can also explain many of the conflicting observations. Indeed some studies included still working patients while others included only severe off-work patients with 'failed back surgery syndromes'.

In summary, there is a general agreement that a lack of fitness, either as a cause or a consequence of chronic pain, plays a significant role in the development and/or the perpetuation of chronic pain, as witnessed by the fact that 'physical deconditioning' occupies a central

place in the biopsychosocial model presented in figure 1. Hence, physical fitness evaluation is relevant and useful. However, valid and reliable methods to assess fitness in patients with pain still need to be more precisely identified and described. In response to Stieg's statement that physical testing was futile ¹⁵², Rudy and Stacey state that, on the contrary, neglecting physical aspects of disability would be futile ¹⁴¹.

1.3. VALIDITY AND RELIABILITY OF TRADITIONAL PHYSICAL TESTS AS APPLIED TO PATIENTS WITH PAIN

Validity of a test may simply be defined as how precisely a measure approximates the actual quantity or quality of the variable being assessed¹⁸¹. A reliable (reproducible, repeatable) test has the property of yielding consistent results under varying circumstances¹⁸¹.

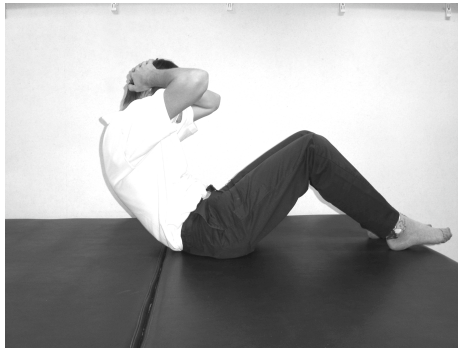
As early as 1969, the results of a study by Nachemson et al. suggested that trunk muscle strength could be decreased in patients with low back pain¹¹³. Numerous subsequent studies focused on trunk muscle strength in patients with back pain, since a strength deficit in those muscles was long thought to be at the origin of chronic and/or recurrent low back pain. Hence, trunk muscles strengthening workouts have traditionally been included in most physiotherapy programs for patients with low back pain. Much effort has thus been done to evaluate trunk muscle strength through varied methods whose reliability has often been debated.

In the following section we will briefly review traditional strength and flexibility tests that have been used to evaluate patients with back pain and comment on their reliability as found in the literature. This topic will also be discussed in the section on 'maximal versus submaximal physical tests in patients with pain' (see Chapter 3, General Discussion).

1.3.1 Trunk muscle strength tests in patients with back pain

Trunk muscle strength can be evaluated through non-dynamometric tests, static and dynamic dynamometric tests (Figure 2).

Dynamic dynamometric tests can either be isoinertial (constant load simulating lifting) or isokinetic (constant speed, varying load that is constantly adapted using a sophisticated computer-interfaced system).



A



B



C



D

Figure 2 : Methods to evaluate trunk muscle strength

- (A) Non-dynamometric dynamic abdominal muscle strength evaluation.
- (B) Dynamometric static evaluation of lifting capacity.
- (C) Dynamic isokinetic lifting capacity evaluation (Cybex Lifttask®)
- (D) Dynamic isokinetic trunk flexion-extension evaluation (Cybex TEF®)

Simple non-dynamometric spinal strength testing methods have been shown to be reliable in healthy subjects ³. However, when used in patients with pain, the greater variability in the results indicates a poorer reliability. For instance, Harding et al. found a moderate reliability of several simple non-dynamometric strength tests in patients with chronic pain ⁵⁶.

Static dynamometric testing of trunk muscle strength allows more precise quantification of strength ²⁶. Robinson et al. studied the reliability of static back extension in varied positions using static dynamometry and found it good except in positions close to full extension ¹³⁸.

Dynamic trunk muscle evaluation was developed to simulate every day physical activity that strains trunk musculature as trunk flexion, extension and rotation against resistance, and lifting.

Dynamic dynamometric testing can either be isoinertial (i.e., lifting tasks) or isokinetic. The Isostation B-200 is a sophisticated isoinertial system that measures trunk muscle strength against a preset constant resistance during movement in different planes. In such traditional systems, the movement velocity changes according to the amount of force or torque the subject is able to apply along the full amplitude of movement. The B-200 system also features simultaneous mobility measurement capability in all three axes. Although less popular than the isokinetic systems, the B200 has been used in several studies to study trunk strength ^{91, 94, 154, 155} and, as mentioned before, trunk motion patterns ^{155, 156}.

Sophisticated isokinetic machines have been developed to study for specific movements of a joint or a part of the body maximal strength throughout a complete range of movement at various constant preset velocities ⁹⁷. Such systems are computer-interfaced and custom software performs extensive data analysis and presentation. Although expensive,

they are sometimes thought to allow more 'quantitative' or 'objective' spinal function assessment ^{31, 81, 97}. Newton and Waddell have extensively reviewed the literature on trunk strength testing with so-called 'isomachines' which includes both isoinertial and isokinetic systems in healthy subjects and back patients ¹¹⁷. They note that only two reliability studies have included back patients and studied short-term validity in one test session. They concluded that, in normal subjects, only trunk extension and flexion strength (with both systems) and lifting (Cybex ® LIFTASK) can reliably be evaluated with 'isomachines' at speed below 120°/sec. They also stressed that reliability of trunk strength testing in other planes (rotation, lateral flexion) is unsatisfactory. It must be emphasized that reliability can only be achieved after very carefully controlling standardized testing conditions such as position of the subject, selection of speeds, and instructions given to the subject ^{26, 95, 117, 160}. Newton et al. also conducted a remarkable study specifically aimed at evaluating the value of the Cybex II® isokinetic back testing system in trunk strength testing of normal subjects and patients with chronic low back pain ¹¹⁶. Most of the patients included in the study (78%) were unselected primary general practitioner referrals. Patients with radicular pain, previous spinal surgery and compensation claims were excluded. In any case, they found most of the isokinetic trunk strength measures highly reliable in both healthy subjects and patients with chronic or recurrent low back pain. Noteworthy, a significant gain in performance between first and second trial in test-re-test procedures has often been reported during strength testing in patients with pain ^{29, 65, 72, 116}. This gain is generally attributed to a learning effect ¹¹⁷ although other factors may also intervene, as it will be more extensively discussed here below. Hence, only a second test session

conducted on a separate day should ideally serve as baseline value ¹¹⁷. Otherwise, if trunk strength is evaluated on the basis of a first test session before rehabilitation, the patient's strength capacity will be underestimated and, consequently, progress after treatment will be confounded with a so-called 'learning effect'.

Observation of trunk strength testing of patients with back pain often suggests that the effort of some patients may not be truly maximal. The magnitude of the 'learning effect' observed in patients with pain raises questions about the validity of the first strength measure.

'Iso-machines' allow extensive data collection and analysis during dynamic trunk movements or lifting tasks. Specifically developed software allows calculation of various indices and graphic presentation of most important data. Among them, several variability indices and other methods are proposed to reflect how maximal the effort of the subject is ^{38, 58, 59, 132, 154}.

As an example, the Cybex® system software calculates an 'average points variance' index (APV index) on the basis of the force-angle curves variability which supposedly reflects how maximal the effort was. Newton et al. studied the value of this APV index as a 'consistency of effort' index and concluded that it was invalid and unreliable as an indicator of how truly maximal the effort was ¹¹⁶. The validity of strength testing in such subjects remains questionable. Newton notes that there is no direct evidence on the relationship between isokinetic measures and actual muscle strength ¹¹⁷. Hirsch et al. reported a strong relation between poor performance on isoinertial trunk strength testing and so-called 'non organic' or behavioral signs as assessed by the Waddell score ⁶⁰. After studying serial trunk dynamometry, Cooke et al. noted that the measured strength improvements were greater than muscle physiology could explain²⁹ and

concluded that a strength test in patients with pain should be considered more as a psychophysical test than as a valid measure of muscle capacity. In our opinion, any result obtained through maximal strength testing should always be considered as a psychophysical variable, even in healthy subject. In patients with pain, pain itself and numerous other factors will also interfere with the expression of full actual physical capacity. This issue will be more extensively discussed in the general discussion.

A higher variability in strength testing results observed in patients with pain is sometimes interpreted as malingering. The term 'sincerity of effort' has been used suggesting that patients with pain might not be 'sincere' during physical testing¹⁴⁰. It is obviously unacceptable that legal decisions against back-injured workers may be taken on the basis of such methods¹⁵². Nevertheless, as recalled by Newton and Waddell, 'isomachines' have been used as 'spinal lie detectors' to detect malingerers¹¹⁷.

1.3.2. Range of motion, mobility tests in patients with back pain

Varied spinal mobility tests (Figure 3) are routinely used during clinical examinations, such as the Schöber index, straight-leg-raising, lateral bending and sit-and-reach tests. Relatively simple inclinometers have also been developed to assess more specifically spinal mobility independently from hip mobility¹⁰⁰. Finally, spinal mobility may also be assessed by more sophisticated devices such as isoinertial and isokinetic trunk dynamometers^{116, 117, 154}.

The reliability of range of mobility measures or indices is generally considered to be acceptable when test conditions are well standardized and controlled^{49, 51, 70, 82}.

Dillard et al. showed that sophisticated and expensive isoinertial and isokinetic systems were no more reliable in assessing mobility than simple goniometers or inclinometers ³⁴. Gill et al. studied the reliability in evaluating lumbar range of motion of the finger-to-top distance, of a modified Schober index (Figure 3, A), of inclinometry (Figure 3, B) and of a photometric technique ⁵¹. They showed that, although the reliability of such methods was poor in general, simple modified Schober method was acceptable for clinical, routine, non-invasive lumbar mobility assessment. In any case, angle measurements smaller than 5° are not reliably detected by goniometry in healthy subjects ²¹.



A



B

Figure 3 : Lumbar range of motion as evaluated by : (A) a modified Schober index and, (B) inclinometry ⁵¹.

1.3.3. Extensive physical fitness evaluation through batteries of tests

In patients with back pain, Mayer et al. were the first to implement a thorough physical function battery of tests mainly focusing on trunk function (strength and flexibility) but also including cardio-respiratory endurance and coordination tests ⁹⁷⁻⁹⁹ (Table I). They called this physical capacity battery of tests a 'novel objective functional measurement for low back pain patients' ⁹⁸.

TABLE I

TESTS OF PHYSICAL FUNCTION USED IN THE PRESENT STUDY

Tests	Description
1. Spinal range of motion A. Gross lumbar range B. True lumbar range C. Straight leg raising	A quantitative non-invasive measure of trunk range of motion in the sagittal plane involving measurement of inclination at the T12-L1 interspace (gross motion) minus the inclination of the pelvis (hip motion), giving an actual measure of the T12-S1 motion segments (true lumbar in flexion and extension). A straight leg raising is an effort measure when compared to pelvic flexion.
2. Isometric and multi-speed isokinetic dynamic trunk strength utilizing Cybex (Lumex Corp., Ronkonkoma, NY) flexion/extension trunk strength tester	Measures torque output in standing (functional) position isolating trunk musculature in flexion and extension. Results compared to normal database normalized to subject body weight.
3. Cardiovascular fitness/muscular endurance measures A. Bicycle ergometry B. Upper body ergometry	Standardized tests of lower and upper body ergometry under increasing work loads. End point is target heart rate at 85% maximum or fatigue.
4. Gait speed	Measurement of stride length and cadence over measured course.
5. Obstacle course	Timed test simulating activities of daily living and work requiring subject to complete tasks in multiple positions.
6. Static lifting	Lifting dynamometer using standard static lifting test protocol.
7. Lifting underload	Dynamic lifting done frequently through a full range of motion, floor to waist and waist to above shoulder.
8. Global effort rating	Rating of effort by therapists involved in quantitative testing based on nonorganic signs and consistency measures obtained from 1 to 7.

A novel 'objective' extensive physical evaluation of patients with chronic low back pain by Mayer et al. (1986) ⁹⁸. Such thorough physical evaluation includes most fitness components assessment such as mobility (flexibility), static and dynamic muscular strength, cardiorespiratory endurance and coordination.

Unfortunately, Mayer et al., only poorly addressed the issue of the validity and the reliability of traditional physical capacity assessments as applied to patients with pain. Most of the tests included in Mayer's battery have indeed not been validated in patients with pain. As recalled by Williams, the reliability and usefulness of such tests should be considered cautiously because of their highly idiosyncratic nature ¹⁸¹. As Williams noted, precise measures obtained by sophisticated computer-interfaced systems should not be confounded with reliable, valid and relevant measures.

Harding et al. studied a battery of simpler physical tests that were more easily applicable to patients with chronic pain ⁵⁶. All tests could be administered in a total of 45 minutes, and they evaluated most components of fitness. The reliability of most tests was found to be good except for one-leg stance tests designed to evaluate balance.

It is only later that validity and reliability of physical testing procedures in patients with pain was studied more specifically ^{3, 34, 55, 56, 61, 70, 72, 116, 117, 119, 135, 159}. Nevertheless, the very significant gains in physical capacity and the even more spectacular return-to-work rates reported by Mayer et al. after so-called 'functional restoration programs' contributed to popularize their approach ^{98, 99}.

In summary, many methods have been developed and proposed to assess trunk muscle strength and mobility, from simplest to most sophisticated ones. Studies designed to address the reliability of such methods have shown that acceptable reliability could be obtained, but only after carefully controlling the test conditions, which also must be precisely defined and standardized. Although expensive, well-conducted isokinetic trunk flexion and extension strength evaluations are reliable

in patients with back pain. However, reliability does not necessarily imply validity. The issue of the validity of physical tests requiring maximal effort from the subject will be addressed more extensively in the general discussion.

CHAPTER 2: MAIN RESULTS

In this section, our personal contribution to the field of physical capacity assessment and physical reconditioning in patients with chronic pain is presented. In a little more than ten years, most of our clinical research work was oriented towards assessing CRE of patients with pain. Our involvement in the treatment programs of such patients led us to discern the need for a simple, acceptable, valid and reliable tool that could be used in routine clinical practice to evaluate CRE in patients with chronic pain.

2.1. CRE OF PATIENTS WITH CHRONIC PAIN AS EVALUATED BY A NEW ORIGINAL CRE INDEX; VALIDITY, RELIABILITY OF THE $PWC_{65\%}/KG$

We first developed an original multi-stage submaximal cycle ergometer test during which only heart rate (HR) is measured. On the basis of the HR versus Power relationship, a physical working capacity (PWC) index reflecting CRE is calculated: the $PWC_{65\%}/kg$.

We conducted several cross-sectional studies aimed at evaluating CRE of patients with different chronic pain syndromes. In several of our studies, we addressed the validity and reliability of that new CRE index. Most of our personal contribution in the field of CRE evaluation in patients with pain can be found in the following papers:

- Nielens, H. and L. Plaghki. Evaluation of physical adaptation to exercise of chronic pain patients by a step-test procedure. *The Pain Clinic*. 1:21-28, 1991..... p 27

- Nielens, H. and L. Plaghki. Perception of pain and exertion during exercise on a cycle ergometer in chronic pain patients. *Clin J Pain.* 10:204-209, 1994..... p 35
- Nielens, H., V. Boisset, and E. Masquelier. Fitness and perceived exertion in patients with fibromyalgia syndrome. *Clin J Pain.* 16:209-213, 2000..... p 41
- Nielens, H., D. Cornet, and F. Rigot. Maximal versus submaximal testing protocols to evaluate fitness of patients with chronic low back pain; abstract. *Med Sci Sports Exerc.* 34, 2002..... p 73
- Nielens, H. and E. Masquelier. The role of exercise in the treatment of fibromyalgia: An overview. *Int Sportmed J.* 2:1-8, 2001..... p 55

2.2. PERCEIVED EXERTION AND CHRONIC PAIN

The original multi-stage cycle ergometer test developed by us also allows calculation of an original Rate of Perceived Exertion (RPE) index, the RPE_{65%}, on the basis of RPE scores obtained on a Borg scale during the test. The RPE_{65%} is an original and unique tool as it reflects RPE of the subject, which has been evaluated at different exercise intensities. Using the RPE_{65%}, we showed that exertion perception could be very different according to the nature of chronic pain. Our findings led to important conclusions that should be implemented during physical reconditioning of patients with pain. Our publications addressing the issue of exertion perception in patients with chronic pain are the following:

- Nielens, H. and L. Plaghki. Perception of pain and exertion during exercise on a cycle ergometer in chronic pain patients. *Clin J Pain.* 10:204-209, 1994..... p 35

- Nielens, H., V. Boisset, and E. Masquelier. Fitness and perceived exertion in patients with fibromyalgia syndrome. *Clin J Pain*. 16:209-213, 2000..... p 41

2.3. PHYSICAL ACTIVITY LEVEL OF PATIENTS WITH CHRONIC PAIN

Finally, we also conducted a study assessing physical activity (PA) level in patients with chronic pain to verify our previous hypothesis stating that chronic pain affects male patients more than female patients. Another study including PA assessment in individuals with end-stage renal disease led us to address the issue of the validity of traditional PA questionnaires as applied to chronically ill and sedentary individuals in general. Most of our published contributions in understanding how chronic pain and end-stage renal disease affect every day physical activity can be found in:

- Nielens, H., T. M. Lejeune, A. Lalaoui, J. P. Squifflet, Y. Pirson, and E. Goffin. Increase of physical activity level after successful renal transplantation: a 5 year follow-up study. *Nephrol Dial Transplant*. 16:134-140, 2001..... p 47
- Nielens, H. and L. Plaghki. Cardiorespiratory fitness, physical activity level, and chronic pain: are men more affected than women? *Clin J Pain*. 17:129-137, 2001..... p 63

2.4. PUBLICATIONS

2.4.1.

Original articles

Evaluation of physical adaptation to exercise of chronic pain patients by a step-test procedure

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summary

Since usual testing procedures for assessing physical adaptation to exercise are not designed for chronic pain patients, we conceived and evaluated a discontinuous, submaximal, gradational step-test. In this test, the subjects are asked to carry out at least three, and if possible four or more, 2 min stages at the end of which the heart rate (HR) is measured. The work intensity (P) of each stage is calculated by applying the following formula: $P = \text{subject weight} \times \text{platform height} \times \text{climbing frequency} \times \text{gravity}$. The heart rate:work intensity relationship is calculated and this allows for calculation of the submaximal work capacity (P_{65} per cent/kg) at a heart rate of 65 per cent of maximal theoretical heart rate for age. After validity and reliability of the test have been discussed on the basis of test-retest procedures and comparison with the well-known cycloergometer test conducted along the same protocol, physical adaptation to exercise of 56 chronic pain patients (27 males, 29 females) and 42 healthy subjects (21 of each sex) was evaluated by this testing procedure. The submaximal work capacity of male chronic pain patients is found to be significantly lower compared with healthy male subjects. This appears to confirm the existence of a deconditioning syndrome. Surprisingly, no significant difference is found for female subjects. This sex-related difference of the impact of chronic pain on submaximal work capacity might be the result of socio-cultural factors in our subjects.

Key words: low back pain; rehabilitation; work capacity evaluation.

introduction

The benefit of exercise programmes in chronic pain is generally accepted since chronic pain patients are prone to a low physical activity level which might play an important role in the chronic pain syndromes. In a recent review, Williams¹ has emphasized the importance of considering the physical capability, as well as the neurological status and psychological factors in the evaluation of the chronic pain patient. Although the impact of chronic pain on physical adaptation to exercise is often mentioned, there is a consistent lack of physiological data.

Since usual work capacity testing procedures are not designed for chronic pain patients, we used and evaluated a discontinuous, largely submaximal, gradational step-test based on commonly accepted procedures for aerobic performance assessment.^{2,3} This multi-stage test allows the determination of a submaximal (aerobic) work capacity index (P_{65} per cent/kg) calculated by interpolation on the basis of the heart rate:work intensity (power) relationship observed throughout the test. We prefer a step-test procedure essentially for its greater flexibility and because lower work intensities can be chosen.

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The validity and reliability of this test will be assessed. The effect of chronic pain on exercise capacity as measured by this testing procedure shall also be discussed.

materials and methods

The subjects

We evaluated a group of 56 chronic pain patients and a group of 42 healthy subjects. All chronic pain patients were recruited in the Chronic Pain Care Unit of the Cliniques Universitaires St Luc in Brussels, Belgium between 1987 and 1989. The chronic pain patient group was mainly composed of patients complaining of lumbo-radicular pain (64 per cent) and low back pain (16 per cent). All patients had at least a 6 month history of pain, most of them having suffered for many years; 57 per cent had failed to respond to one or several surgical treatments. Patients on cardiotropic medications were discarded from this study. The healthy subjects were volunteer members of the medical staff. They received no financial benefit for participating in the study. For both groups, age, sex, weight and height of each subject were recorded (Table I). In the chronic pain patient group, diagnosis as well as medication were also noted.

Table I.
Anthropometrical data (mean $\pm$ s.d.)

Sex	Chronic pain patients		Healthy subjects	
	Male	Female	Male	Female
<i>n</i>	27	29	21	21
Age (years)	42.9 $\pm$ 10	47.2 $\pm$ 13	36.8 $\pm$ 12	42.5 $\pm$ 14
Weight (kg)	78.5 $\pm$ 11.1	65.8 $\pm$ 10.6	73.9 $\pm$ 9.3	63.3 $\pm$ 9.1
Height (m)	1.73 $\pm$ 0.08	1.64 $\pm$ 0.06	1.75 $\pm$ 0.08	1.66 $\pm$ 0.05

The step-test

Four wooden platforms (0.5 $\times$ 0.5 m) of different heights (0.07, 0.12, 0.19 and 0.24 m) which can be superimposed were used as stairs. The heart rate (HR) was monitored during the entire effort with a sport tester PE 3000TM programmed to obtain a value every 5 s.

Our step-test was organized according to the usual protocol of submaximal, gradational, discontinuous tests for aerobic performance evaluation.^{2,3} After a 2 min resting period, the subject was asked to step up and down the first platform (0.07 m) for 2 min following the step frequency given by a metronome (usually 84 steps/min = 21 climbs/min): this period is referred to as stage 1. The subject was then allowed to rest sitting on a chair for approximately 2 min. We continued in this manner for the following stages with higher platforms (0.12, 0.19, 0.24 m). The subject was asked to complete at least three stages and sometimes four depending upon the final stage heart rate which should at least reach 120 beats/min. Only the resting heart rate (HR0) measured after the 2 min resting period in the seated position, and the heart rate at the end of each stage steady states (HR1, HR2, HR3, etc.) were recorded for further analysis (Fig. 1).

For each stage the power (*P* in watts) developed by the subject was calculated as follows:

$$P = w \times h \times f \times g \text{ where, } \begin{aligned} w &= \text{body weight in kg} \\ h &= \text{platform height in metres} \\ f &= \text{climbing frequency in climbs/s} \\ g &= \text{gravity (9.8 m/s}^2\text{)} \end{aligned}$$

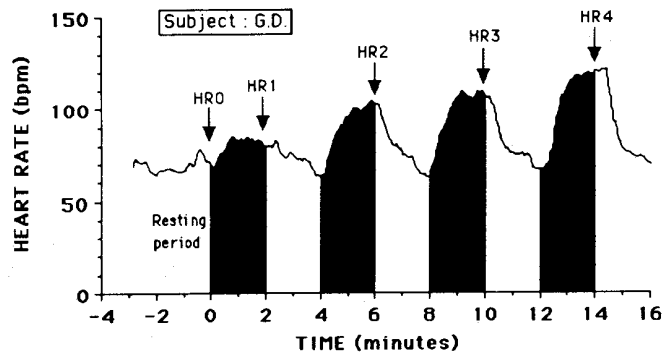


Figure 1. Heart rate monitoring during gradational step-test for subject GD. Shaded areas correspond to work periods of increasing work intensity at the end of which heart rate is recorded (HR1, HR2, HR3, etc).

The cycloergometer test

The cycloergometer test was conducted on a Puch Tunturi™ cycloergometer following the same protocol: 2 min working periods alternating with 2 min of rest. The pedalling frequency was maintained at a constant rate of 60 revolutions/min. The power in watts is given directly by the ergometer work intensity scale.

P65 per cent/kg the submaximal work capacity index

The linear relationship^{2,3} between power and heart rate is then computed by a least squares regression procedure.

The heart rate corresponding to 65 per cent of maximal theoretical heart rate (HR65 per cent) is computed as follows:^{3,4}

$$\text{HR65 per cent} = (\text{HR}_{\text{max}} - \text{HR0}) 0.65 + \text{HR0}$$

where $\text{HR}_{\text{max}} = 220 - \text{age in years}$

For each subject, the P65 per cent at HR65 per cent was interpolated on the basis of the calculated work intensity:heart rate relationship (Fig. 2). Finally, P65 per cent was expressed in watts per kg of body weight: P65 per cent/kg

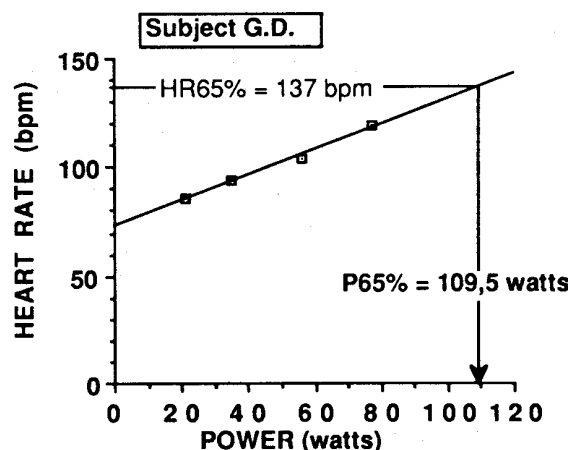


Figure 2. Relationship of heart rate vs work intensity (power in watts) for subject GD. A regression line is fitted by a least squares regression procedure giving the following parameters: slope = 0.58; intercept = 73.4 beats/min; $r = 0.9958$. The power (P65%) corresponding to a heart rate of 65 per cent of maximal theoretical heart rate (HR65 per cent = 137 beats/min for subject GD) is obtained by interpolation and equals 109.5 W.

(W/kg). P65 per cent/kg is the submaximal work capacity index obtained for each subject of this study.

results

Submaximal work capacity index of chronic pain patients and healthy subjects

Table II gives the mean submaximal work capacity index, standard deviation and range for chronic pain patients and healthy subjects. While these results seem to indicate a reduction in adaptation to exercise of male chronic pain patients ($t = -3.39$; $P = 0.001$), no significant difference is found among female subjects ($t = -0.78$; $P = 0.441$).

Validity and reliability of the submaximal work capacity index

Determination of the heart rate:work intensity relationship. In order to evaluate the validity of the submaximal work capacity index it is necessary to review several factors which play an important role in the heart rate:work intensity relationship calculation and thus in the submaximal work capacity index determination.

The mean HR1 of all the tests conducted on the chronic pain patients was $100 \pm 13/\text{min}$ versus $96 \pm 14/\text{min}$ for healthy subjects. The mean heart rate range which reflects the work intensity range of tests was $22 \pm 8/\text{min}$ for chronic pain patients and $26 \pm 10/\text{min}$ for healthy subjects. Sixty-six per cent of all chronic pain patients completed three stages of tests, while this was the case for only 43 per cent of the healthy subjects. The remaining subjects completed four or more stages. The mean correlation coefficient (r) of the calculated heart rate:work intensity relationship equalled $0.9907 (\pm 0.0134)$ for chronic pain patients and $0.9902 (\pm 0.0151)$ for healthy subjects.

Table II.
P65 per cent/kg of chronic pain patients and healthy subjects

	P65 per cent/kg of chronic pain patients (W/kg)		P65% per cent/kg of healthy subjects (W/kg)	
	Male	Female	Male	Female
Mean	1.29*	1.01(NS)	1.74*	1.08(NS)
s.d.	0.39	0.25	0.53	0.40
Range	0.45–1.99	0.42–1.40	0.73–2.78	0.44–2.40

* $P = 0.001$.

NS = not significant.

Step-test vs cycloergometer test. In order to compare our step-test with a cycloergometer test conducted the same way, we submitted eight male healthy subjects to both methods of testing. Both tests were conducted one after the other, separated by 10 min of rest, in a random order. Table III shows the submaximal work capacity index measured by both testing procedures. There is no statistical difference in the submaximal work capacity index obtained by either testing procedure (mean difference = 0.045 ± 0.153 W/kg, paired t value = 0.834 ; $P = 0.432$).

Test-retest reliability. In order to evaluate the test-retest reliability of the step-test we submitted four healthy subjects and eight chronic pain patients to five successive tests. All five tests were conducted on different days within a 3 week period. The eventual medication of the chronic pain patients was not modified during this testing period. Table IV shows the five consecutive submaximal work capacity indices measured in the two categories (chronic pain patients and controls) of subjects. A two factor repeated measures analysis of variance gave the following results: the P65 per cent/kg is significantly

different between the two categories of subjects ($F = 14.92$; $P = 0.003$) as can be expected from the data given in Table II. The statistics of the repeated measures factor ($F = 1.12$; $P = 0.361$) and the interaction of the two factors ($F = 0.25$; $P = 0.910$) verify the hypothesis of reliability of the submaximal work capacity index measure.

Table III.
Step-test vs cycloergometer

Subjects	P65 per cent/kg step-test (W/kg)	P65 per cent/kg cycloergometer (W/kg)
DD	1.36	1.61
FM	1.6	1.61
HN	2.26	2.35
LH	1.79	1.68
PW	1.92	1.73
EX	1.81	1.71
JLT	2.07	1.95
LS	1.22	1.03
Mean $\pm$ s.d.	1.75 ± 0.35	1.71 ± 0.37

Table IV.
Reliability of the step-test

Subjects	Category of subjects	P65 per cent/kg of five tests (W/kg)
HN	1	2.34; 2.46; 2.44; 2.62; 2.70
AG	1	2.39; 2.04; 2.22; 2.17; 2.38
DD	1	1.66; 1.70; 1.74; 1.63; 1.63
JLT	1	2.16; 2.24; 2.06; 1.91; 1.96
RA	2	1.66; 1.65; 1.61; 1.35; 1.58
BC	2	0.92; 0.96; 1.20; 1.14; 1.12
BL	2	1.35; 1.42; 1.35; 1.28; 1.82
MD	2	0.81; 0.77; 0.68; 0.69; 0.80
SM	2	1.71; 1.86; 1.74; 1.55; 1.70
MC	2	1.86; 1.61; 1.48; 1.46; 1.32
SA	2	1.23; 1.38; 1.69; 1.44; 1.44
LC	2	0.97; 1.16; 1.58; 1.33; 1.64

Categories: 1 = healthy subject; 2 = chronic pain patients.

Effect of drugs

Since cardiotropics can influence the heart rate:work intensity relationship we discarded systematically from the study patients medicated with such drugs. Moreover, many chronic pain patients are under psychotropic medication which have an anticholinergic effect.⁵ In order to track this eventual effect, we classified the chronic pain patients into two groups: those taking any psychotropic agent (category A, $n = 17$) and those without psychotropic medication (category B, $n = 39$). Since anti-inflammatory drugs and minor analgesics have no known effect on heart rate adaptation, patients taking such medications are included in category B.

Category A has a mean submaximal work capacity index of 0.96 ± 0.400 W/kg, statistically lower ($t = 2.867$; $P = 0.006$) than the category B mean index of 1.23 ± 0.297 W/kg.

discussion

Validity and reliability of the submaximal work capacity index, effect of drugs

The heart rate:work intensity relationship is well known to be linear for heart rates between about 100/min and 160–170/min. In order to be confident that the measurements fit a linear model, the following three rules have to be respected. First, work intensity of the first stage must be chosen high enough to raise the heart rate to approximately 100/min since the lower heart rates are

more susceptible to influence by external factors, such as anxiety, distraction etc., which might possibly invalidate the heart rate:work intensity curve and be responsible for bias in the parameter calculation. The mean values of HR1 for all subjects ($100 \pm 13/\text{min}$ for chronic pain patients and $96 \pm 14/\text{min}$ for control) are in agreement with this concept. Second, work intensity of the final stage should not be too high so that the heart rate remains below ± 85 per cent of maximal theoretical heart rate for age. This was certainly the case since the heart rate at the end of the final stage of all tests was always close to $120/\text{min}$. Finally, the work intensity range should be wide enough to obtain a sufficient heart rate range. When testing young healthy subjects a range in the heart rate of about $50\text{--}60/\text{min}$ was normally encountered. This is generally impossible with chronic pain patients because of the pain induced by exercise. We calculated a mean heart rate range of $22 \pm 8/\text{min}$ for chronic pain patients. This low value might be responsible for a loss of accuracy in the determination of the heart rate:work intensity relationship.

The correlation coefficients (r) calculated for each heart rate:work intensity relationship have to be greater than 0.9969 for three-stage tests and greater than 0.9500 for four-stage tests for sufficient confidence ($P = 0.05$) that the heart rate:work intensity calculated relationships fit a linear model. This is the case in 44.5 per cent of the three-stage tests and 100 per cent of the four or more stage tests. These results point to another potential loss of accuracy of the method. Among young healthy subjects four to six stages are usual which, of course, is impossible for chronic pain patients. Anyhow, it should go on to a fourth stage test whenever possible. Finally, it must be pointed out that no significant difference is found between three-stage and the four or more stage test submaximal work capacity index among healthy subjects. It seems thus that a lower number of stages, such as three, does not give rise to a systematic error in the estimation of the submaximal work capacity index.

While the validity of cycloergometer tests has been widely documented it is less common to evaluate subjects with gradational step-tests. As shown in Table III, there is no significant difference of the submaximal work capacity index, whatever the testing procedure (paired $t = 0.83$; $P = 0.432$). No significant difference is found either for the slopes of the heart rate:work intensity relationships between the two testing procedures, being 0.53 for the step-test compared with 0.54 for the cycloergometer test. These results suggest that there is no difference of the submaximal work capacity index whether the subject is tested with a step-test or with a cycloergometer, and this confirms the validity of our step-test.

Statistical analysis of the test-retest results (Table IV) clearly demonstrates the reliability of the testing procedure for healthy subjects as well as for chronic pain patients.

The fact that the submaximal work capacity index of category A chronic pain patients, that is those on psychotropic drugs, is significantly lower (Student's t -test = 2.867; $P = 0.006$) might reflect the anticholinergic effect of these drugs on the heart rate:work intensity relationship. If this pharmacological effect on the submaximal work capacity index is true, it would mean that the index of medicated subjects would often be systematically underestimated. However, these results must be analysed with caution since any difference in the submaximal work capacity index between medicated and non-medicated patients could also be due to the gravity of their respective diseases, as only the worst cases will have been treated. Although no final conclusions can be drawn on the basis of these data, the probable effects of psychotropic medication on the submaximal work capacity index must be kept in mind when evaluating the physical adaptation of chronic pain patients. Therefore, dose and time of medication should always be diligently recorded, and eventual changes of medication over time should also always be considered when evaluating the effects of remobilization programmes on the basis of the submaximal work capacity index.

Work capacity of chronic pain patients

Work capacity indices are generally calculated on the basis of a heart rate of 170/min. We chose a heart rate at 65 per cent for two reasons: first, because for older subjects a heart rate of 170/min is close to the maximal theoretical heart rate; this value is thus outside the linearity range of the heart rate:work intensity curve for older subjects and no such interpolation should be done on the basis of a regression line equation, as previously calculated; second, during the rehabilitation exercise programmes, a work intensity corresponding to a heart rate at 65 per cent is often required for optimal training effect.⁴ It seems then more pragmatic to calculate a work capacity index at that heart rate. The calculated heart rate:work intensity relationships in healthy subjects are in agreement with previous data in the literature for healthy subjects of both sexes.^{2,6} The difference in the submaximal work capacity index between male chronic pain patients and healthy subjects is highly significant ($t = -3.39$; $P = 0.001$); this difference remains significant even when the male chronic pain patients on psychotropic medication are eliminated from the statistical analysis ($t = -3.13$; $P = 0.003$). These results verify for our male subjects the hypothesis of the existence of the "deconditioning syndrome" proposed by Mayer *et al.*⁷ and many other authors.^{8,9} Our results indeed suggest a global loss of aerobic performance in male chronic pain patients which could be more directly observed through utilization of oxygen consumption measurements.^{10,11}

On the other hand, no significant difference of the submaximal work capacity index among female subjects was found. It seems to us that the most acceptable hypothesis is that chronic pain has a different impact on the work capacity of female as compared with male chronic pain patients. We believe that this might be due to socio-cultural factors; 66 per cent of female chronic pain patients had no occupational activity before pain started and thus did not lose it. Among the 10 female patients who had been working, only five had to leave their job. Moreover, most female chronic pain patients managed to maintain almost normal levels of housekeeping duties while 74 per cent of their male counterparts, after losing their jobs, had very low levels of daily life activity. Although attractive, this hypothesis must still be verified using, for instance, actometer techniques,¹² or, more simply, activity level scaling. The fact that chronic pain syndromes might exist without any loss of work capacity, as observed in general among female patients and individually in some male chronic pain patients, must however, not be forgotten.

conclusion

In this study we measured the submaximal work capacity index (P_{65} per cent/kg) of 56 chronic pain and 42 healthy subjects by a gradational step-test procedure. After studying the validity and reliability of this technique we believe that this testing procedure has at least three advantages over other methods:

1. An optimal reproducibility in the work intensity determination since no calibration is necessary.
2. An optimal flexibility in the work intensity determination by choice of various step frequencies and platform heights. This makes the choice of the low work intensities used with chronic pain patients easier than with cycloergometry.
3. The low cost of the equipment used in the study.

Our results prove the existence of the "deconditioning syndrome" proposed by many authors. However, chronic pain does not affect all patients to the same extent; male subjects are the most affected in our population. Further studies should be conducted aimed at explaining this observed sex difference in chronic pain.

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Perception of Pain and Exertion During Exercise on a Cycle Ergometer in Chronic Pain Patients

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Abstract:

Hypothesis: Chronic pain patients (CPP) are generally thought to present with reduced fitness in relation with pain enhancement during exercise. A distortion of exertion perception may coexist, which could lead CPP to reduce physical activities.

Design: Case-control study, with a nonrandomized consecutive sample that was age matched.

Setting: A Chronic Pain Unit in a Multidisciplinary Pain Center of a university hospital in a city of >1,000,000 inhabitants.

Subjects: 42 CPP referred for evaluation and 34 controls (staff members and relatives).

Outcome measures: Fitness index and exertion perception index was obtained by a cycle ergometer test. Trend analysis was performed on pain scores reported on a visual analogue scale during exertion.

Results: Male CPP mean fitness index was found to be significantly reduced. No difference in exertion perception was found between groups. Trend analysis of reported pain revealed that 49% of CPP showed a positive trend, 5% a negative trend, and 46% showed no significant trend as exercise intensity increased. There was no significant relation between type of trend and fitness nor exertion perception index.

Conclusions: Only male CPP have a reduced work capacity. Exertion perception seems normal among CPP. The possible distortion of exertion perception as a causal factor in the reduced fitness of CPP has to be rejected. Lack of significant correlation between type of trend of pain while exercising on a cycle ergometer and fitness index shows that one should be careful in proposing that reduced fitness is only related to pain enhancement during exercise in CPP.

Key Words: Chronic pain—Physical fitness in chronic pain—Pain during exercise—Exertion perception and pain—Cycle ergometry.

Chronic pain syndrome is now a well-recognized medical entity (1). Nevertheless, the paucity of studies devoted to the physical consequences of chronic pain are in contrast to the considerable amount of information collected during the past decades regarding the involvement of cognitive, emo-

tional, and behavioral factors. As a corollary, a multitude of tests is readily available to evaluate the psychological status of chronic pain patients (CPP), but few techniques have been described and validated for the physical assessment of these patients.

In recent years, several authors reported that chronic pain may in some circumstances rapidly induce a syndrome of physical deconditioning sometimes reported as a disuse syndrome (2–4). However, some categories of CPP seem more likely than others to develop a disuse syndrome. For instance, Nielens and Plaghki (5) found in a group mainly of

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chronic low back pain patients a significant reduction of work capacity only among males. These authors proposed sociocultural factors to interpret this sex difference of the impact of chronic pain on physical fitness. Furthermore, within each category, some individuals were more affected than others. Thus, several questions remain regarding the mechanisms underlying the reduced work capacity observed among CPP.

It is generally believed that patients reduce physical activity simply to avoid pain enhancement. A pain and exercise avoidance behavior may rapidly develop, favored as it often is by numerous social and medical contingencies. This interpretation, based on the behavioral model proposed by Fordyce et al. (6), has gained general acceptance and has left little room for alternative interpretations. Nevertheless, we would like to stress the fact that this model can only be valid if pain is actually enhanced by exercise; i.e., if there is a clear relation between deconditioning and pain increase during exercise.

The first goal of the present studies is to examine CPP's pain reports while they exercise in order to find out whether pain is generally enhanced by exercise and to verify if there is a negative correlation between the intensity of exercise-induced pain and work capacity.

The second goal is to evaluate how CPP perceive exertion. Because distortions of perceptions have already been reported in CPP (7), one may hypothesize that CPP perception of exercise intensity is higher when compared to that of healthy subjects. Such a phenomenon could secondarily lead CPPs to avoid exercise, or at least to reduce its intensity, which in time could also result in a disuse syndrome. Exertion perception was assessed using the Rate of Perceived Exertion (RPE) scale proposed by Borg and Linderholm (8). Hence, this study also has to examine the validity of the RPE scale in the context of chronic pain syndromes. This may have practical value, as physicians regularly prescribe exercise for rehabilitation of CPP and seek to use the RPE scale as an aid in the prescription and management of exercise programs.

MATERIALS AND METHODS

Subjects

The first group, or CPP Group, consists of 42 CPP (23 males and 19 females; between 25 and 57

years of age; mean 41 ± 8.2 years) being followed at the time of the study in the Chronic Pain Unit of the Department of Physical Medicine and Rehabilitation (Cliniques Universitaires St-Luc, Brussels, Belgium). The tests were conducted as part of a general clinical assessment program for all consecutive patients referred, during the period of the study, to the Chronic Pain Unit incorporated in a Multidisciplinary Pain Center in a university hospital of a city of $>1,000,000$ inhabitants. Most of these patients complained of pain in the lumbo-sacral area often radiating to the lower limbs; see Table 1 for the distribution of pain localizations. They had previously undergone an average of 0.8 unsuccessful surgical procedures related to their pain. All patients suffered for >1 year and most of them for several years when the study was conducted. The use of cardiotropic or psychotropic medications was an exclusion criterion, because such drugs may alter the heart rate response to exercise.

The second group, or Controls, consists of 34 healthy subjects (17 males and 17 females; between 19 and 57 years of age; mean 39 ± 8.3 years) recruited from among the members of the medical staff or their relatives. They were age matched ($F = 0.73$; $p = 0.394$) with the CPP Group. The body weight of the Controls was slightly, although significantly lower ($F = 4.58$; $p = 0.036$), than in the CPP Group (mean difference for males = 6.1 kg and for females = 5.8 kg).

Apparatus

All subjects were asked to perform a gradational cycloergometer test. The bicycle ergometer was a Monark model 818E. Heart rate (HR) was measured by the Sport Tester PE 3000. The RPE was assessed with the latest 10-point version of the RPE scale (9). This discrete psychometric scale, which has ratio properties, is presented in Table 2.

Patients were also asked to score their pain on a 10-cm visual analogue scale (VAS) annotated with the words "no pain" and "maximum of pain" at the

TABLE 1. Pain localizations in CPP

Pain localization	n	Percentage
Cervical	1	2.4
Lumbar	6	14.3
Lumbo-radicular	24	57.1
Cervical, dorsal, and lumbar	6	14.3
Other localization	5	11.9
Total	42	100%

TABLE 2. Rate of perceived exertion (Borg scale, 1982)^a

Score	Perceived exertion
0	Nothing at all
0.5	Very, very weak
1	Very weak
2	Weak
3	Moderate
4	Somewhat strong
5	Strong
6	
7	Very strong
8	
9	
10	Very, very strong
.	Maximal

^a Ref. 9.

appropriate end (10) and presented on a white sheet of paper. All patients were carefully instructed in the use of both scales before the test.

Procedures

The bicycle ergometer test was graded, submaximal, and multistaged. The protocol will only be briefly described here since it is generally accepted in exercise physiology (11).

All subjects were first familiarized with the equipment and the use of the psychometric scales. During a resting period in a seated position, subjects were asked to score their pain perception on the VAS (VAS_r).

Starting at 25 W, the work intensity (power in watts) was then increased in steps of 25 W every 2 min. All subjects were able to reach at least a fourth stage (corresponding to a power of 100 W). Some patients were asked to perform a fifth stage (125 W) in order to reach a minimum HR of 140 beats/min (bpm) unless they were forced to stop pedalling by major enhancement of pain. At the end of each 2-min stage, HR was recorded and the patients were asked to score their perceived pain and exertion respectively on the VAS and RPE scales. These data were recorded as HR₁, VAS₁, and RPE₁ for stage 1, HR₂, VAS₂, and RPE₂ for stage 2, and so on until the last stage, which in most cases was the fourth stage.

After the test, HR versus power, VAS scores versus HR, and, finally, RPE scores versus HR curves were plotted.

Two different indices were calculated for each subject: a work capacity index ($W_{65\%}/\text{kg}$) and a rate of perceived exertion index (RPE_{65%}).

Work capacity index ($W_{65\%}/\text{kg}$)

In sports physiology, the work capacity at 170 beats/min of HR/kg of body weight is widely used as an aerobic fitness index since it strongly correlates with maximal oxygen uptake (11). Among CPP, we preferred to use a work capacity index at 65% of maximum HR ($W_{65\%}$). Indeed, although an HR of 170 is easily reached by young athletes, in most cases it is out of reach for CPP, firstly because of their older age and secondly because of their disability. In other words, $W_{65\%}$ represents a workload corresponding to the same relative work intensity for all subjects regardless of their age. Another advantage of using such a work capacity index is that it can be obtained without any oxygen uptake measurements, but simply with an ergometer and a heart rate meter which perfectly suits clinical use in chronic pain care units. In a previous study (5), the authors showed the reliability of such an index obtained with a step-test among CPP.

Calculations for the $W_{65\%}$ per kg of body weight, or $W_{65\%}/\text{kg}$ index, are graphically illustrated in Fig. 1. The first step consisted in computing the linear regression between power (watts) and HR by a least squares method. In the next step, HR corresponding to 65% (HR_{65%}) of maximal heart rate (HR_m) using the formula proposed by the American College of Sports Medicine (12) was calculated:

$$\text{HR}_{65\%} = (\text{HR}_m - \text{HR}_r) \cdot 0.65 + \text{HR}_r$$

where $\text{HR}_m = 220 - \text{age in years}$, and HR_r was assumed to be 80 bpm in all patients. Then, the power at HR_{65%}, i.e., $W_{65\%}$, was computed by interpolation, using the regression parameters of the

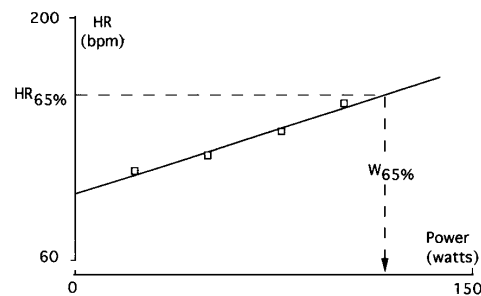


FIG. 1. To obtain the work capacity index ($W_{65\%}/\text{kg}$), we first computed the linear relationship HR–Power by a least squares method. $W_{65\%}$ was then calculated by interpolation of the power in watts for HR_{65%}. $W_{65\%}$ was divided by the weight of the subject expressed in kg. Thus, $W_{65\%}/\text{kg}$ is the work capacity per kg of body weight of the subject exercising at 65% of his or her theoretical maximal HR.

linear HR versus power relationship. Finally, $W_{65\%}$ is divided by the body weight in order to obtain $W_{65\%}/\text{kg}$ (in watts per kg of body weight: W/kg).

Rate of perceived exertion index ($RPE_{65\%}$)

A rate of perceived exertion index, $RPE_{65\%}$, was computed for each subject as follows: First, the parameters of the linear regression RPE versus HR were obtained by a least squares procedure. Then, the $RPE_{65\%}$ was obtained by computing the RPE corresponding to $HR_{65\%}$ (calculated as above) by using the parameters of the linear regression. This procedure is graphically illustrated in Fig. 2.

Pain evaluation and exercise

Analysis to detect any monotonic trend in pain evaluation during exercise was based on the relative ordering of all pairs of VAS scores (13). In short, given a time series $VAS_r, VAS_1, \dots, VAS_n$, let

$$q_{ij} = 1 \text{ if } VAS_i < VAS_j \quad \text{when } j > i$$

otherwise $q_{ij} = 0$.

Then let

$$Q = \sum_{i < j} q_{ij}$$

Q is the number of discordances in the series. Since there are $\frac{1}{2}n(n-1)$ pairs of scores, it follows that the expected value of Q

$$E(Q) = \frac{1}{4}n(n-1)$$

If $Q > E(Q)$ this indicates a rising trend of pain, whereas $Q < E(Q)$ suggests a falling trend of pain. Q is related to the rank correlation coefficient τ of Kendall (14) so that

$$\tau = 1 - \frac{4Q}{n(n-1)}$$

under H_0 , $E(\tau) = 0$ and

$$\text{var}(\tau) = \frac{2(2n+5)}{9n(n-1)}$$

The test statistic z is then computed by

$$z = \frac{\tau}{\sqrt{\text{var}(\tau)}}$$

A positive trend in pain evaluation during a session of exercise is rejected when $z > -1.645$ ($p > 0.05$).

Statistics

Data are presented as means $\pm$ standard deviations. Group differences in means were evaluated

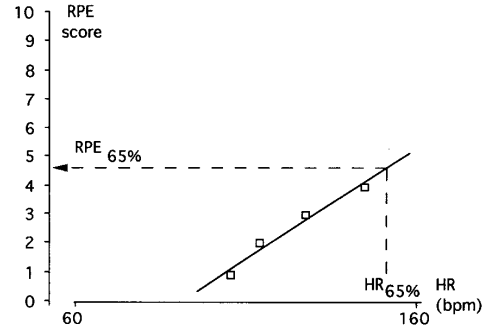


FIG. 2. To calculate the exertion perception index $RPE_{65\%}$, we first calculated the linear relationship RPE versus HR by a least squares procedure. The $RPE_{65\%}$ was obtained by interpolating the RPE score on the vertical axis for $HR_{65\%}$.

using a two-factor (sex and groups) analysis of variance (ANOVA). Post hoc testing with Scheffe's F test was used to identify significant differences. Contingency table analysis was based on the χ^2 goodness of fit test. Critical values which reached the $p < 0.05$ level were considered as statistically significant.

RESULTS

Work capacity: $W_{65\%}/\text{kg}$

There was no significant difference in $HR_{65\%}$ between groups or between males and females within groups.

The results concerning the work capacity index $W_{65\%}/\text{kg}$ are presented in Table 3 (Controls and CPP). A two-factor ANOVA (sex and groups) showed a significant difference in $W_{65\%}/\text{kg}$ between males and females ($F = 16.99$; $p = 0.0001$) and between Controls and CPP ($F = 20.40$; $p = 0.0001$). As the interaction ($F = 7.54$; $p = 0.008$) is also significant, it points toward a difference between the groups depending on sex. Contrast analysis confirms that the mean difference between male CPP and male Controls (0.80 W/kg) is statistically significant ($F = 24.58$; $p = 0.0001$). However, among female subjects, the difference in $W_{65\%}/\text{kg}$ between both groups (0.195 W/kg) is not significant ($F = 1.74$; $p = 0.196$).

TABLE 3. Fitness index: $W_{65\%}/\text{kg}$

$W_{65\%}/\text{kg}$ (watts/kg)	CPP	Controls
Male	1.62 ± 0.325^a	2.42 ± 0.677^a
Female	1.47 ± 0.429	1.66 ± 0.458

^a $p = 0.0001$.

The slope, but not the intercept, of the HR–power relationship is significantly different ($F = 33.79$; $p = 0.0001$) between male (0.47 ± 0.16) and female subjects (0.68 ± 0.15) and allowed interpretation of the sex difference in the $W_{65\%}/\text{kg}$. Exactly the opposite is observed between male Controls and male CPP, as the intercept rather than the slope of the HR versus power relationship was significantly different ($F = 18.38$; $p = 0.0001$; HR of Controls = 71.8 ± 11.45 bpm and for CPP = 84.59 ± 7.399 bpm). Thus, the difference in $W_{65\%}/\text{kg}$ may be considered as the consequence of a rigid upward shift of the HR–power relationship in male CPP.

Perception of pain during bicycling exercise in CPP

The intensity of clinical pain scored on the VAS during the rest period and subsequent exertion test in the CPP Group was submitted to a trend analysis. In this group, 20 patients (49%) showed a positive trend and two patients (5%) a negative trend in clinical pain intensity as strength of exercise increased with time. The remainder ($n = 19$; 46%) showed no significant trend in pain intensity. There was a clear influence of sex ($\chi^2 = 5.52$; $p = 0.019$) as female patients had a higher rate of positive trends ($n = 12$, 72%) than the male patients ($n = 8$, 33%). However, there was no significant statistical link between the type of trend (positive and absent or negative) and $W_{65\%}/\text{kg}$ or $\text{RPE}_{65\%}$.

Rate of perceived exertion: $\text{RPE}_{65\%}$

The results of the rate of perceived exertion index, or $\text{RPE}_{65\%}$, are shown in Table 4. The two-factor ANOVA (sex and groups) shows no significant difference in $\text{RPE}_{65\%}$ between males and females ($F = 0.01$; $p = 0.969$) or between Controls and CPP ($F = 0.17$; $p = 0.682$), and no interaction ($F = 0.34$; $p = 0.562$).

There was no significant difference in the slopes (0.1 ± 0.04), the intercepts (-8.90 ± 5.085) or the thresholds HR of the RPE versus HR linear relations between groups.

DISCUSSION

Chronic pain may induce a syndrome of physical deconditioning. The present studies were under-

taken to examine possible mechanisms leading to this syndrome. We first examined CPP's pain reports while they exercised in order to find out whether pain was generally enhanced by exercise, since such a situation can lead to an exercise-avoidance behavior. Nevertheless, we only found a positive trend in clinical pain enhancement by exercise in less than half of the patients, and, moreover, no relation was observed between physical capacity indices and pain score variations during exercise. Second, exercise intensity perception was also explored since a distortion of exertion perception could lead to the same behavior and secondarily to a reduced physical capacity. However, no difference in the ratings of perceived exertion could be noted between CPP and healthy subjects.

Chronic pain and fitness

The significant reduction in $W_{65\%}/\text{kg}$ among male CPP tends to confirm the generally accepted hypothesis of a reduced physical capacity being one element of chronic pain syndromes (2,15). Surprisingly, such a diminished $W_{65\%}/\text{kg}$ is not observed among female patients. These results are in agreement with our previous study (5) and stress again the possible sex difference in the impact of chronic pain on the activity level of patients of our population, probably in relation to sociocultural factors: women in our population perhaps being kept more active by their numerous household tasks. It is important to note that mean $W_{65\%}/\text{kg}$ results in the present study were higher than those obtained with a step-test in a previous study (5). The differences between $W_{65\%}/\text{kg}$ that remain the same for all groups of subjects are probably due to differences in power calibration of the ergometers as well as in the method used to calculate the power developed during the step-test.

Pain during exercise

One of the most commonly accepted hypotheses postulates that reduced physical capacity of CPP is a consequence of exercise-increased or exercise-induced pain that may affect CPP and lead them to avoid every-day life activities and exercise. Thus, it seemed interesting to monitor perception of pain intensity during the exertion test. Therefore, we asked all patients to score their clinical pain on a VAS before and at the end of each stage. Analysis showed that 72% of the female patients and only 33% of the male patients had a positive trend toward pain enhancement.

TABLE 4. Rate of perceived exertion index: $\text{RPE}_{65\%}$

$\text{RPE}_{65\%}$	CPP	Controls
Male	6.08 ± 2.493	6.18 ± 2.431
Female	6.39 ± 2.890	5.82 ± 1.942

Furthermore, there was no significant relation between the trend of pain intensity and the indices of physical fitness ($W_{65\%}/\text{kg}$) and of perceived exertion ($\text{RPE}_{65\%}$). These findings may suggest that pain increase due to exertion does not seem to be relevant in explaining the reduced physical capacity of CPP. Moreover, exercise capacity of female patients is, on average, less frequently affected by chronic pain than that of male patients.

Nevertheless, we have to be cautious as pain scores reported by CPP during the tests only characterize exertion on a bicycle ergometer. It may be possible that other kinds of exercises would be less tolerated. As a matter of fact, it is not unusual to observe that a CPP is hardly able to walk at a slow speed or even stand up for more than a few minutes, although that patient can still bicycle, sometimes for half an hour or more. We think that further studies should be conducted to analyze pain reported during different kinds of exercises that are more similar to domestic or occupational activities.

Exertion perception in CPP

Measures of submaximal exercise tolerance in a healthy subject may be estimated with sufficient accuracy by a RPE scale as well as by measuring HR at different workloads during the exercise test (8). Even more, RPE scores seem to be fairly independent of age and sex. During bicycle ergometer exercise tests, there is a threshold at 20–30% of maximum power followed by a linear increase in the numerical ratings for perceived exertion. This linear relationship between RPE and HR shows little interindividual variation in healthy subjects of the same age and sex (16).

The perception of exertion by CPP is a largely unexplored field. Whereas nociceptive stimuli may be perceived differently in CPP, little is known about how those patients feel when they exercise. Are they able to discriminate pain from exertion while exercising, does pain modify exertion perception? If exertion perception is distorted in CPP, this phenomenon could well be considered as playing a role in the onset of the deconditioning syndrome. For example, if exertion is perceived as higher than it actually is, CPP may reduce intensity of everyday life activities and tend to avoid exercises in general that may of course indirectly lower their physical fitness.

When we analyze mean RPE's versus HR relationships, we found no significant difference of

mean slopes and intercepts between CPP and Controls. These results lead us to consider first that, as in healthy subjects, the perception of exertion by the RPE scale is valid and second that perception of exertion is not different among CPP in general. Furthermore, CPP probably discriminate well between the perception of clinical pain and the perception of exertion. Thus, the hypothesis of a possible bias of exertion perception as being an etiopathogenic factor responsible for any reduced aerobic capacity of CPP has to be rejected.

Finally, these results show that clinical use of the RPE scale among CPP can be proposed as an aid in exercise prescription, at least in chronic low back pain associated with sciatica. In this context, $\text{RPE}_{65\%}$ may be considered as a practical index suitable for clinical use.

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Fitness and Perceived Exertion in Patients With Fibromyalgia Syndrome

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Abstract:

Objective: The aim of this study was to evaluate the cardiorespiratory fitness and perceived exertion of female patients with fibromyalgia syndrome (FMS) compared with that of healthy female subjects.

Design and Subjects: This was designed as a cross-sectional case-control study, with a consecutive sample of 30 female patients with FMS and an age-matched control group of 67 healthy female subjects.

Setting: This study was conducted at the multidisciplinary pain center of a university hospital in a city of more than 1 million inhabitants.

Outcome Measures: A cardiorespiratory fitness index ($PWC_{65\%}/kg$) and an original perceived exertion index ($B_{65\%}$) were obtained from the heart rates and perceived exertions scored on a 10-point Borg scale during a submaximal cycle ergometer test. Average indexes for the FMS patients and control subjects were compared.

Results: The mean cardiorespiratory fitness index of the FMS patients was not significantly different from that of the controls. The mean perceived exertion index in the FMS patients was significantly greater than that of the controls, meaning that the FMS patients systematically reported higher ratings of perceived exertion during exercise.

Conclusions: Cardiorespiratory fitness, as expressed by a submaximal work capacity index, seems normal in female patients with FMS compared with age- and sex-matched healthy individuals. The fact that FMS patients overscore their perception of exertion may be due to a greater overlap of peripheral pain and perceived exertion perceptions during exercise. This observation should be noted when using perceived exertion scores to prescribe and monitor exercise in FMS patients.

Key Words: Borg scale—Exercise—Fibromyalgia—Fitness evaluation—Perceived exertion—Rehabilitation

Fibromyalgia syndrome (FMS) is characterized by widespread axial skeletal pain and pain on palpation of at least 11 of the 18 tender point sites.¹ This condition results in debilitating pain and fatigue, which are present at rest and usually increase with exercise.

It is generally admitted that therapeutic management of FMS must include correction of sleep disturbances,

improvement of aerobic fitness by light dynamic exercise, and reinforcement of the internal locus of control by coping strategies.^{2–4}

It has previously been reported that FMS patients may be characterized by an enhanced perception of exertion^{5–7} in contrast to a normal perception of exertion in non-FMS chronic pain patients (CPPs).⁸ An amplified perception of exertion might cause FMS patients to prolong their debilitating condition by keeping them from being sufficiently physically active. Moreover, it is necessary for a physician to verify the perceived exertion of a patient before prescribing a particular intensity of exercise. Therefore, this study mainly aims at assessing the

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perception of exertion in patients with FMS compared with that of control subjects, using an original perceived exertion index.

A second objective of this study was to compare the cardiorespiratory fitness of female FMS patients with that of control subjects so as to determine the relevance of commonly prescribed exercise programs.

MATERIALS AND METHODS

Subjects

Thirty consecutive female patients (age, 46.9 ± 7.8 years [mean $\pm$ SD]) with FMS were included in the study. All patients had been referred to the Chronic Pain Unit of the Physical Medicine and Rehabilitation Department of the Cliniques Universitaires Saint-Luc, a university hospital in Brussels, which is a city of more than 1 million inhabitants. They were all examined by the same permanent staff member, who confirmed the FMS diagnosis according to the American College of Rheumatology criteria.¹ After the initial clinical examination, patients' fitness and perception of exertion were assessed by means of the cycle ergometer test described below.

During the same period, control measurements were performed in 67 age-matched healthy female subjects (age, 45.1 ± 7.7 years) from the hospital staff and their relatives. These subjects were healthy, pain-free, and not taking any medication at the time of the study.

Materials

The following equipment is used to conduct the cycle ergometer test:

1. A cycle ergometer (model 818E from Monark; Vansbro, Sweden)
2. A heart rate (HR) monitor (Sport Tester model from Polar; Kempele, Finland)
3. The latest 10-point version of the Borg rating of perceived exertion (RPE) scale⁹
4. A 10-cm visual analog scale (VAS) presented to the patient on a sheet of white paper

Cycle ergometer test

The cycle ergometer test has been described previously⁸ and is a graded multistage submaximal test of fitness. Starting at 25 W, the power is increased in steps of 25 W in each of three or four 2-minute stages. The test is stopped when the patient's HR reaches 65% of the HR reserve ($HR_{65\%}$) according to the Karvonen formula. All subjects were familiarized with the equipment, the Borg scale, and the VAS before the measurements.

Calculation of the fitness index

A linear relation between the power in watts (W) and the HR (beats per minute) at each stage was calculated by

the least squares fit procedure: $W = a \times HR + b$, where a is the slope and b the intercept of the calculated linear relation.

For each subject age, the HR corresponding to 65% of the HR reserve was calculated according to the Karvonen formula: $HR_{65\%} = (HR_{\max} - HR_{\text{rest}}) \times 0.65 + HR_{\text{rest}}$, where the maximal HR was estimated from the formula $HR_{\max} = 220 - \text{age}$ (in years). The resting HR was assumed to be 80 beats per minute in all subjects to avoid any bias due to an elevated HR_{rest} caused by stress or a methodological flaw in the HR_{rest} measurement.

The power corresponding to $HR_{65\%}$ was measured by means of the wattage versus HR relation and divided by body weight (kilograms) to obtain the cardiorespiratory fitness index, $PWC_{65\%}/\text{kg}$ (Fig. 1). This index represents the mass specific power output at the relative work intensity corresponding to the $HR_{65\%}$ for that subject. Because the $HR_{65\%}$ is calculated as a function of age, subjects of different ages may be compared, which is not possible with more commonly used submaximal work capacity indexes such as the PWC_{150} or PWC_{170} .¹⁰ The validity and reliability of this index as an indicator of cardiorespiratory fitness has been demonstrated in a previous study, where it was obtained with by a step-test procedure.¹¹

Calculation of the perceived exertion index

The perceived exertion index ($B_{65\%}$) was calculated from the Borg score versus the HR linear relation ($B = a \times HR + b$) in a manner exactly analogous to the fitness index calculation (Fig. 2). The Borg score corresponding to $HR_{65\%}$ was taken as the $B_{65\%}$ and is the theoretical perceived exertion index value the subject would score on the 10-point Borg scale when exercising at the power corresponding to $HR_{65\%}$. This index thus allows com-

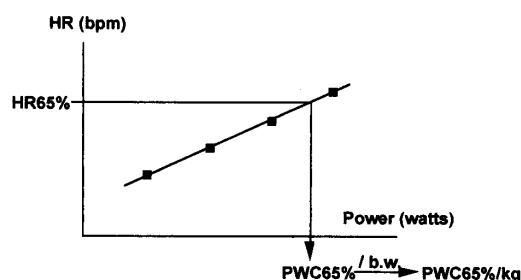


FIG. 1. The procedure used to calculate the $PWC_{65\%}/\text{kg}$ fitness index. First, a linear relation is calculated by the least square fit method on the heart rate (HR) measured at the end of each of the n stages (four stages shown) versus the corresponding exercise intensities (Power). The power corresponding to the heart rate at 65% of the HR-reserve ($HR_{65\%}$) is determined from the graph, and finally the $PWC_{65\%}/\text{kg}$ is obtained by dividing that power by body weight (kg).

parison of exertion perception in subjects of different ages and levels of fitness at the same relative power output.

Pain perception at rest and during the cycle ergometer test

Patients are first asked to score their pain perception while at rest on the cycle ergometer (VAS_{rest}). If a patient reported more than one painful area, she was asked to score only the most painful one. At the end of each stage of the cycle ergometer test, the HR was recorded and the patients were asked to score their exertion and pain perceptions on two different scales to help differentiate between the pain and exertion perceptions.

An exercise-related pain index, the $VAS_{65\%}$, was calculated in a manner similar to the $B_{65\%}$ calculation. This index was obtained from a linear plot of VAS scores versus HR at the $HR_{65\%}$ point. As with the $B_{65\%}$, the $VAS_{65\%}$ roughly approximates the pain VAS score that the subject would report if exercising at an intensity corresponding to the $HR_{65\%}$.

Finally, the Spearman rank correlation coefficient between the $B_{65\%}$ and $VAS_{65\%}$ was calculated to evaluate whether perceived exertion and pain perceptions are correlated in FMS patients.

RESULTS

Mean values and SDs for the $PWC_{65\%}/kg$ and $B_{65\%}$ are presented in the Table for both the experimental and control groups. The mean $PWC_{65\%}/kg$ of the patients was not significantly different from that of the controls ($F = 3.1$, $p = 0.08$). The mean $PWC_{65\%}/kg$ of the patients may also be expressed as the z score value cal-

TABLE 1. Fitness index ($PWC_{65\%}/kg$) and Borg rating of perceived exertion index ($B_{65\%}$) of patients with fibromyalgia syndrome and controls

	$PWC_{65\%}/kg$ (W/kg) (mean $\pm$ SD)	$B_{65\%}$ (mean $\pm$ SD)
Fibromyalgia syndrome patients (n = 30)	$1.52 \pm 0.42^*$	$8.2 \pm 3.47^\dagger$
Controls (n = 67)	$1.67 \pm 0.39^*$	$4.9 \pm 1.56^\dagger$

* $p = 0.08$.

$^\dagger p < 0.0001$.

culated on the basis of the $PWC_{65\%}/kg$ obtained in controls as follows:

z score of patients = (mean of patients – mean of controls)/SD of controls

The z score value calculated for the mean fitness index of the patients was -0.38 .

The significant difference observed between mean RPE indexes of the two groups in this study (ANOVA: $F = 40.7$, $p < 0.0001$) demonstrates that at the same relative work intensity, the FMS patients perceived exertion as more intense than did the controls. On average, patients scored about 3.3 points higher than controls on the same 10-point Borg scale when they exercised at a moderate intensity level.

The mean VAS_{rest} obtained in the FMS patients before the test was 3.3 ± 2.4 cm. The mean $VAS_{65\%}$ obtained when exercise intensity reached a level corresponding to $HR_{65\%}$ was calculated to be 6.5 ± 3.0 cm, demonstrating a significant (paired t test = 5.7 , $p < 0.0001$) increase of pain perception in the FMS patients. Twenty-five of the 30 patients in this study reported higher pain scores during exercise compared with their pain score at rest, 2 patients reported the same pain score, and 3 patients reported lower pain scores while exercising on the cycle ergometer.

The Spearman ρ correlation coefficient relating $VAS_{65\%}$ and $B_{65\%}$ was 0.66 , suggesting that those variables correlate significantly ($z = 3.53$, $p = 0.0004$).

DISCUSSION

Cardiorespiratory fitness of FMS patients

In this study, the mean $PWC_{65\%}/kg$ of female FMS patients was not found to be significantly different from that of the healthy age- and sex-matched controls ($p = 0.08$). Furthermore, the difference in cardiorespiratory fitness observed between groups in this study cannot be clinically (i.e., functionally) relevant because the z score (-0.38) obtained for the $PWC_{65\%}/kg$ in the FMS patients lies in the normal range for such physiologic parameters.

These results are in good agreement with those of previous studies, which also involved submaximal

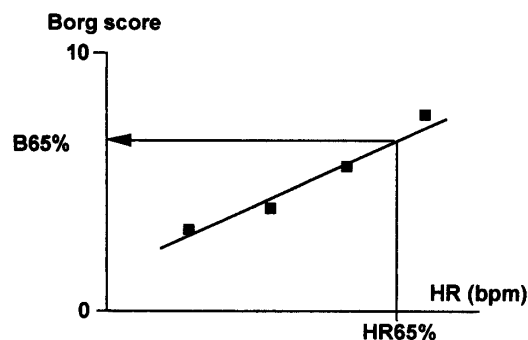


FIG 2. The procedure used to calculate the $B_{65\%}$ perceived exertion index. As for the $PWC_{65\%}/kg$ calculation, a linear relation of the Borg scores versus the corresponding heart rate (HR) at the end of each stage of the test (a four-stage test is shown) is calculated with the least squares fit method. The $B_{65\%}$ perceived exertion index is equal to the Borg score corresponding to an HR of 65% of the HR-reserve of the subject.

testing protocols such as the Astrand 6-minute submaximal cycle ergometer test.⁵ Our results seem to conflict with those of other studies in which a reduced maximum oxygen consumption, $\text{VO}_{2\text{max}}$, was found in FMS patients.¹²⁻¹⁴ These latter studies directly measured oxygen uptake at the end of graded exercise tests in which maximal performance was expected from the subjects. As observed by several authors who have used such maximal protocols, only a few FMS subjects were able to reach a plateau in oxygen uptake or in HR at the end of the test, indicating that level achieved was symptom-limited rather than metabolically limited.^{12,15} Consequently, maximal testing protocols probably systematically underestimate the true maximal aerobic power in FMS patients as is the case in CPPs in general.

Submaximal exercise capacity may be close to normal in FMS patients, who tolerate more intense exercise poorly and are usually incapable of reaching exertion levels close to maximal. This conclusion raises questions about the usefulness of "physical reconditioning programs" as part of a comprehensive treatment program for FMS patients. In any case, the fact that cardiorespiratory endurance is probably not significantly reduced in FMS patients demonstrates that in most cases, improving cardiorespiratory fitness should not be the main goal of such a program from which many other positive effects may be expected.^{3,4,16,17}

Exertion perception of FMS patients

The mean $B_{65\%}$ was on average 3.3 points higher on a 10-point Borg scale in the FMS patients than in the control subjects. Similar findings have been reported by other investigators,^{5,7} who observed higher exertion perception ratings in relatively small groups of FMS patients. A similar phenomenon has also been described in chronic fatigue syndrome patients,^{18,19} which underlines the similarities that characterize these conditions.

As Borg²⁰ recently recalled, perceived exertion and pain are two concepts that partly overlap. Even in healthy subjects, intense exercise may be perceived and described as painful, making discrimination between the two perceptions impossible at high intensities. In normal exercising subjects, there seems to be a continuum in the perception of exertion, which becomes pain perception at high exercise intensity with a transition zone where both concepts overlap. Because FMS patients commonly describe even light muscular activity as unpleasant or painful, their transition zone may extend down to lower intensity exercises. This would make it difficult or impossible for such patients to discriminate exertion from pain perception even at low exercise intensities. The $B_{65\%}$ may partly reflect peripheral muscle pain enhancement in the FMS patients during the cycle ergometer test, in

which case, their RPE scores should parallel their VAS scores for pain during exercise. To test this hypothesis, we calculated the Spearman rank correlation coefficient relating pain perception during exercise as expressed by the $\text{VAS}_{65\%}$ and exertion perception as expressed by the $B_{65\%}$. We found a significant positive correlation, indicating that at a moderate exercise intensity, pain perception correlated well with exertion perception in the FMS patients. Pain increased with exercise in 83% of the patients in this study, although the remaining 17% reported either no change or reduced pain during the test. In contrast, Nielens and Plaghki⁸ reported that in a group of 42 patients with low back pain (with or without sciatica), only 49% of the subjects reported an increase in pain during the same test, and they also reported normal exertion perception as measured by the $B_{65\%}$. Moreover, in a separate group of 54 consecutive CPPs involved in a study on the effect of physical reconditioning (report submitted by Nielens H. and Plaghki L.), we again found a significant correlation between the $\text{VAS}_{65\%}$ and the $B_{65\%}$ in 13 FMS patients (Spearman $\rho = 0.78$, $p = 0.007$), although the correlation was not significant in the 41 remaining non-FMS patients (Spearman $\rho = 0.22$, $p = 0.16$). These findings tend to confirm that FMS patients perceive exertion and pain as progressively increasing during the test probably due to a greater overlap of exertion and pain sensations in exercising muscles, a situation that does not exist in non-FMS CPPs. Conversely, there is evidence that abnormal perceptual amplification is not restricted to nociception but involves other sensory modalities as well. This hypothesis has led to the concept of a generalized hypervigilance state in fibromyalgia.²¹

These findings have important clinical implications because exercise programs are often prescribed for FMS patients. Exertion-perception and Borg scales are often used as tools to advise patients on workout intensities. Indeed, it has been shown that when FMS patients are asked to exercise at a "moderate," "somewhat hard," or "hard" intensity, they exercise at a low level of cardiovascular stress. Such a low exercise intensity is unlikely to generate significant gains in terms of aerobic fitness. Conversely, if the exercise intensity were set by a "target heart rate" of between 40% and 85% of the HR reserve as is often recommended in aerobic exercise programs,²² it would be excessive in FMS patients given the perceived pain and exertion they would have to endure.

The $B_{65\%}$ is an original RPE index of perceived exertion at different levels of exercise intensity. Both the $B_{65\%}$ perceived exertion index and the $\text{PWC}_{65\%}/\text{kg}$ fitness index are simply calculated from data recorded during the graded exertion test. The fact that perceived exertion is assessed at different intensity levels is useful for

physicians prescribing exercise therapy to FMS patients because traditional advice about optimal exercise intensity is not always valid. Moreover, the $B_{65\%}$ index allows quick and convenient perceived exertion comparisons for statistical purposes.

CONCLUSIONS

One result of this study is that the cardiorespiratory fitness (aerobic power) of female FMS patients seems to be normal. Because aerobic exercise programs are often prescribed for FMS patients, this result indicates that increasing aerobic fitness should not be a major goal of therapeutic programs for these patients.

Female FMS patients clearly perceive exertion as more intense than healthy subjects for the same relative levels of submaximal exercise intensity. This is probably due to the fact that because of the nature of fibromyalgia, exertion and pain perceptions overlap more in FMS patients than in healthy subjects or in most other non-FMS CPPs.

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Increase of physical activity level after successful renal transplantation: a 5 year follow-up study

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Abstract

Background. Physical activity (PA) level of end-stage renal disease (ESRD) patients after renal transplantation (TP) is a largely unexplored field, although it is an important component of quality of life.

Methods. Using the Baecke self-administered and the Five-City Project 7-day PA recall questionnaires, PA level was estimated in 32 consecutive ESRD patients (12 males, 20 females; mean age 45.9 ± 13.1 years; mean dialysis duration 23.5 ± 21.8 months) admitted for renal TP and to whom no exercise programme of any kind was proposed. PA were recorded 1, 3, 6, 12 and 60 months after TP.

Results. Immediate pre-TP PA level of renal transplant candidates was between 18 and 35% less than that of age-matched healthy subjects ($P < 0.05$), depending on gender and questionnaire. After an immediate decrease in PA level 1 month post-TP, mean PA level increased and reached a plateau 1 year after TP. This gain in PA capacity reached 30%, as compared with pre-TP values ($P = 0.06$ to $P < 0.01$). During the fifth year after TP, the mean level of PA was unchanged. A more qualitative analysis, allowed by the sub-score comparisons, showed that although the occupational status of the patients remained the same, they participated significantly more in moderate and even high intensity PA (leisure, sports, household chores) after TP.

Conclusions. Most renal graft recipients are spontaneously more active after TP, an observation consistent with a better quality of life. Therefore, they should be advised precisely about how to resume more strenuous activities such as sports in order to avoid cardiac or musculoskeletal disorders in relation to their weakened pre-TP condition.

Keywords: haemodialysis; physical-activity; questionnaires; rehabilitation; renal-transplantation

Introduction

Physical activity (PA) is an important determinant of health [1]. In chronically ill patients, PA level may become critically low and contribute to worsen the subject's condition. Indeed, as PA level decreases, so do all components of physical fitness. Since fitness may be considered an important determinant of physical capacity [2], a low level of fitness may contribute to an even further decrease in PA level, in a positive feedback manner. PA is thus often thought to be a reliable indicator of quality of life, so that many authors have incorporated PA level assessments in study designs to evaluate the consequences of chronic illness and/or the benefits of a therapy.

Very few data are available for PA level of end-stage renal disease (ESRD) patients on regular haemodialysis (HD) [3,4]. A low PA level is expected in these patients since a decreased functional status has been demonstrated with the Karnofsky scale or the Sickness Impact Profile [5–7] and since low physical fitness has been reported [8]. Data about the PA level of patients who have undergone renal transplantation (TP) are equally scarce [3,9,10]. Such patients would be expected to be more active than prior to TP since their uraemic syndrome is corrected and they don't have to spend 12 h a week on HD treatment. On the other hand, both surgery and steroids administration, with its attendant deleterious effect on muscle metabolism [11] and bone mass [12], are expected to negatively affect rehabilitation.

In order to elucidate the net impact of TP on PA in both the short and long term, we prospectively recorded PA level using two validated questionnaires administered to a population of transplanted patients to whom no exercise programme of any kind was proposed.

Subjects and methods

Patients admitted for TP at the Cliniques Universitaires St-Luc in Brussels between 1 September 1993 and 1 October

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1994 and who intended to be thereafter followed exclusively in our outpatient clinic were eligible. Thirty-two patients (12 males, 20 females) gave informed consent and entered the study. The causes of end-stage renal failure were: chronic glomerulonephritis ($n=10$), autosomic dominant polycystic kidney disease ($n=7$), chronic interstitial nephritis ($n=7$), Alport's syndrome ($n=2$), analgesic nephropathy ($n=1$), diabetic nephropathy ($n=1$), Goodpasture syndrome ($n=1$) and unknown ($n=3$).

Age at inclusion averaged 46.2 ± 9.50 and 46.1 ± 15.30 years for males and females, respectively. Their respective mean weight was 70.3 ± 7.8 kg and 57.6 ± 9.8 kg, with mean body mass indices (BMI) of 23.6 ± 1.93 kg/m² and 22.4 ± 1.13 kg/m² for males and females, respectively. Thirty-one patients were on regular HD before TP for a mean duration of 22.5 ± 21.65 months; one patient had a pre-emptive living-donor TP. The graft originated from a cadaver donor in 29 cases and from a living related donor in three cases. At the time of admission for TP, mean creatinine and haemoglobin were 8.9 ± 2.3 mg/dl and 10.0 ± 1.6 g/dl, respectively. Twenty-three patients were on erythropoietin therapy. Pre-transplant-associated co-morbid conditions were diabetes mellitus ($n=2$) and a previous history of cerebral aneurysm rupture ($n=1$). All patients underwent immunosuppression with 500 mg i.v. methylprednisolone at induction and oral prednisolone. In addition, 21 patients were given cyclosporine and azathioprine, three patients cyclosporine and mycophenolate mofetil, and eight patients tacrolimus and azathioprine. Rejection episodes were treated with three i.v. boluses of 500 mg methylprednisolone. If they proved resistant, a 10-day course of ATG or OKT₃ (Orthoclone®, Cilag Ortho Pharmaceutical Corporation, Raritan, NJ, USA) was given. In the patients for whom anti-hypertensive drugs were necessary after TP, they were prescribed in the following sequence: calcium antagonist, beta-blocker, ACE inhibitor, diuretic.

PA level and weight were measured in all patients 1, 3, 6 and 12 months after TP (t_1 , t_3 , t_6 and t_{12}) as well as during the fifth year after TP (t_{60}). At t_{60} , only 18 patients (nine males, nine females) were available for evaluation. Among the drop-outs, one was lost to follow-up, three had resumed HD, three had died (one sepsis, one anorexia nervosa and one unknown) and seven declined the final evaluation.

PA level evaluation

PA level was determined by both the Baecke [13] and a 7-day recall (the Five-City Project) questionnaires [14], translated into French. Both questionnaires were administered by the same well trained observer for every patient at all six evaluations.

Patients were questioned within the first 15 days following TP about the 1-week period immediately preceding their admission (t_0). This period was assumed to be representative of their habitual PA before TP.

The Baecke self-administered habitual PA questionnaire

The questionnaire was self-administered although, if necessary, active help from the observer was provided. This questionnaire allows calculation of a total PA score, which is the sum of three separate sub-scores (leisure time, sport and occupation). It generally refers to habitual PA. Each evaluation allowed the calculation of four different PA scores: a total PA score ($B_{tot_{0,...,60}}$), a sport-related PA sub-score ($B_{sport_{0,...,60}}$), a leisure-time-related PA sub-score

($B_{leisure_{0,...,60}}$) and an occupation-related PA sub-score ($B_{occup_{0,...,60}}$).

The Five-City Project 7-day recall PA questionnaire

This questionnaire allows calculation of five PA sub-scores: the total amount of time spent per week in sleep or rest ($Rest_{0,...,60}$), and in light intensity ($Light_{0,...,60}$), in moderate intensity ($Mod_{0,...,60}$), in hard intensity ($Hard_{0,...,60}$) and in very hard intensity ($Vhard_{0,...,60}$) PA. All these sub-scores are expressed in hours/week. One MET is defined as the energy expenditure rate for sitting quietly and approximates resting metabolic rate (~ 1 kcal/h/kg). Sleeping or resting, and light, moderate, hard and very hard intensity PA correspond to 1, 1.5, 4, 6 and 10 MET for energy consumption calculation [14] with the Five-City Project questionnaire. To record and classify some activities that were not present on the questionnaire's list, we used the Compendium of Physical Activities from Ainsworth *et al.* [15]. HD time (12 h/week) was arbitrarily considered as bed rest.

The total Five-City Project PA score ($SCPt_{ot_{0,...,60}}$) is obtained by summing the five sub-scores, which have been multiplied by their corresponding intensity level (in MET), and dividing by seven (days/week). These scores thus represent the average daily energy expenditure rate of the preceding week, expressed in kcal/day or in kcal/day/kg body weight, when normalized for body weight.

Analysis

Mean patient weights at t_0 , t_3 , t_6 , t_{12} and t_{60} were analysed by analysis of variance (ANOVA) for repeated measures. As an effect of treatment (TP) on weight is demonstrated, the comparisons between pre- and post-TP mean weights were performed using Student's paired *t* test.

Baseline PA scores obtained with both questionnaires were compared with those of age- and sex-matched healthy subjects [14,16,17], using unpaired Student's *t* test.

ANOVA for repeated measure was conducted on all PA scores with gender as a possible interacting factor. When no gender effect was present, further analysis was conducted on all patients as a single group. When a significant effect of treatment (TP) on PA level was demonstrated, comparisons between pre- and post-TP scores obtained with both questionnaires were performed using Student's paired *t* test.

The Spearman *r* correlation coefficient between baseline total PA scores obtained with both questionnaires was calculated to question the validity of the methodology. For statistical analysis, the significance level was defined as $P < 0.05$.

Results

As expected, serum creatinine and haemoglobin levels were normalized after TP (Table 1). In contrast, blood pressure control requiring a progressive increase in the number of anti-hypertensive drugs was observed. Eleven patients presented one episode of acute reversible graft rejection in the first 6 months post-TP. After TP, several pathological conditions that might have influenced PA scores occurred: cytomegalovirus infection ($n=2$), de novo diabetes ($n=2$), pulmonary emboli ($n=1$), crural paresia ($n=1$), bladder cancer ($n=1$), grand mal seizure ($n=1$), suicide attempt ($n=$

Table 1. Mean serum creatinine and haemoglobin levels ($\pm$ SD), blood pressure (BP), and drug therapy after TP

	<i>t</i> 1	<i>t</i> 3	<i>t</i> 6	<i>t</i> 12	<i>t</i> 60 ^a
Serum creatinine (mg/dl)	1.4 $\pm$ 0.4	1.4 $\pm$ 0.3	1.4 $\pm$ 0.3	1.5 $\pm$ 0.4	1.3 $\pm$ 0.4
Blood haemoglobin (g/dl)	10.7 $\pm$ 1.1	12.1 $\pm$ 2.1	12.4 $\pm$ 1.9	12.8 $\pm$ 1.8	13.3 $\pm$ 1.6
Prednisolone dosage (mg/day) ^b	16 $\pm$ 4.5	10.6 $\pm$ 4.1	9.2 $\pm$ 2.6	7.1 $\pm$ 1.1	6.9 $\pm$ 1.1
Systolic BP (mm Hg) ^c	141 $\pm$ 21	138 $\pm$ 20	140 $\pm$ 17	147 $\pm$ 24	142 $\pm$ 15
Diastolic BP	88 $\pm$ 10	87 $\pm$ 11	88 $\pm$ 10	88 $\pm$ 13	83 $\pm$ 09
Hypotensive drugs requirements	(n)	(n)	(n)	(n)	(n)
1	8	5	9	8	7
2	10	11	10	9	6
3	1	2	2	4	
4	1	1	2		

^aAt *t*60, 18 patients of the cohort were investigated (see text).

^bRepresents the average daily prednisolone intake per patient at a given period of follow-up.

^cBlood pressure (BP) is measured in the recumbant position.

1), peripheral arteritis (*n*=1) and acute myocardial infarction (*n*=1).

After TP, a gradual weight gain was observed in both male and female patients (Figure 1). At *t*6, mean weight gain became statistically significant in males (*P*=0.02) and females (*P*=0.001) compared with *t*0. At *t*60, mean weight had reached a plateau in females but was still increasing in males. Total weight gain over the 5 years post-TP averaged 14% (*P*<0.01 vs *t*0) in males and 9% (non-significance (NS) vs *t*0) in females. This raised mean BMI from 23.6 $\pm$ 1.93 kg/m² and 22.4 $\pm$ 4.13 kg/m² to 27.3 $\pm$ 3.23 kg/m² and 24.6 $\pm$ 5.25 kg/m² in males and females, respectively.

Mean total PA scores obtained at *t*0 with both questionnaires among males and females are summarized in Table 2. Total PA scores from the Five-City

Project questionnaire were expressed in kcal/day to allow comparisons with data available for healthy subjects.

As compared with data from Jacobs *et al.* [17] for the Baecke questionnaire and from Sallis *et al.* [14] for the Five-City Project questionnaire, our patients were significantly less physically active than healthy subjects: on the average, patients' total PA scores were 25% lower than those of healthy subjects.

Table 3 presents all Five-City Project PA sub-scores (mean $\pm$ SD) expressed in hours spent weekly for patients before TP, as well as for controls. Data for healthy subjects were re-calculated from Sallis *et al.* [14] after exclusion of elderly subjects (65–74 years). Mean Rest₀ was 50% greater in HD patients of both sexes. Mean Light₀ was significantly reduced in females

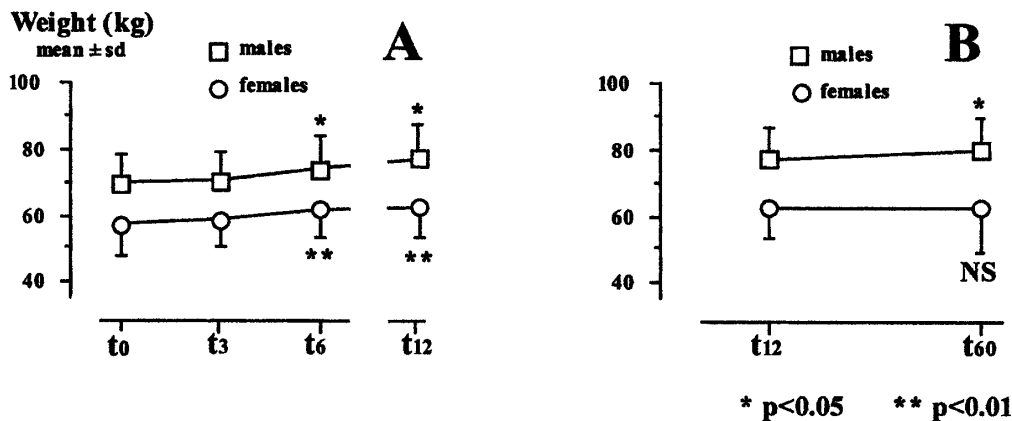


Fig. 1. Evolution of weight after transplantation. After TP, mean weight of male and female subjects gradually increased. (A) The evolution of mean weight of male and female patients during the first year after TP (from *t*0 to *t*12). The increase in weight was already significant at *t*6 in males and females compared with baseline values (*t*0). (B) The evolution of the mean weight (*n*=18) over the next 4 years (from *t*12 to *t*60). As compared with *t*12, weight gain 5 years after TP was still significant in males. In females, weight gain had already reached a plateau 1 year after TP and remained stable further on.

Table 2. Mean ($\pm$ SD) total PA scores of ESRD patients at the time of TP, as compared with healthy subjects

Total PA score (kcal/day)	Sex	Patients	Healthy subjects
Btot ₀	M	5.9 ^c $\pm$ 2.39 (<i>n</i> = 12)	7.6 $\pm$ 1.3 (<i>n</i> = 28) ^a
	F	4.9 ^a $\pm$ 2.27 (<i>n</i> = 20)	7.5 $\pm$ 1.5 (<i>n</i> = 49) ^a
5CPtot ₀	M	2367 ^c $\pm$ 499 (<i>n</i> = 12)	3192 $\pm$ 894 (<i>n</i> = 1006) ^b
	F	1869 ^a $\pm$ 367 (<i>n</i> = 20)	2290 $\pm$ 528 (<i>n</i> = 1120) ^b

^aFrom Jacobs *et al.* [17].^bFrom Sallis *et al.* [14].^c*P* < 0.05; ^d*P* < 0.01.**Table 3.** Five-City Project PA sub-scores of patients before TP compared with healthy subjects

5-CP sub-scores (h/week)	Sex	Patients (12 males, 20 females)	Healthy subjects ^a (911 males, 1000 females)
Rest ₀ (1 MET)	M	71.5 $\pm$ 15.8	50.3 $\pm$ 18.4 ^b
	F	74.3 $\pm$ 10.67	50.4 $\pm$ 16.4 ^b
Light ₀ (1.5 MET)	M	88.1 $\pm$ 11.7	102.4 $\pm$ 34.7
	F	89.2 $\pm$ 12.8	109.2 $\pm$ 22.1 ^b
Moderate ₀ (4 MET)	M	6.9 $\pm$ 8.6	8.5 $\pm$ 22.3
	F	4.1 $\pm$ 7.5	6.6 $\pm$ 16.4
Hard ₀ (6 MET)	M	0.02 $\pm$ 0.1	4.5 $\pm$ 18.1
	F	0.4 $\pm$ 1.4	1.2 $\pm$ 6.3
Vhard ₀ (10 MET)	M	0	2.3 $\pm$ 3.0
	F	0	0.6 $\pm$ 3.2

^aRecalculated from Sallis *et al.* [14] for age-matched subjects.^b*P* < 0.01.

(*P* < 0.01) but not in males (*P* $\approx$ 0.10). None of the 32 uraemic subjects recalled any very hard PA. This observation is probably particularly relevant in males since the data from Sallis *et al.* [14] indicate that healthy males spend an average of 2.3 h/week at very hard PA. Other mean sub-scores (Moderate₀ and Hard₀) for HD patients were lower, but not significantly different from those of healthy controls.

Hence, data obtained with the Five-City Project questionnaire demonstrated a significant reduction in the mean total PA score (expressed in kcal/day) in uraemic patients. In these patients, a shift from very hard and/or light intensities of PA towards rest and/or sleep PA was observed.

The Spearman correlation coefficient calculated between pre-TP Btot₀ and 5CPtot₀ was 0.60 (*P* = 0.0002).

ANOVA of PA scores obtained with both questionnaires at *t*₀, *t*₁...*t*₆₀ demonstrated a significant (*P* < 0.0001) effect of treatment (TP). The fact that no gender interaction (*P* = 0.26) was observed allowed us to treat all patients as a single group for further analysis. Figure 2 shows mean Btot (Figure 2a) and 5CPtot (Figure 2b) at *t*₀, *t*₁...*t*₆₀, expressed in kcal/day/kg. Mean Btot was significantly decreased at *t*₁ and *t*₃; in contrast, the decrease of mean 5CPtot at *t*₁ was not significant. A statistically significant increase of PA level was observed at *t*₆ for 5CPtot, and at *t*₁₂ and *t*₆₀ for both PA scores. One year after TP (*t*₁₂), mean Btot₁₂ was 6.7 $\pm$ 1.9 and 5.5 $\pm$ 2.4, which represents

an increase of 14 and 15% as compared with *t*₀ in males and females, respectively. Mean 5CPtot₁₂ was 36.1 $\pm$ 3.16 and 34.6 $\pm$ 3.86 kcal/day/kg in males and females, which is an increase of 8 and 7% in males and females, respectively. At 12 months post-TP, all total PA scores, with the exception of female Btot₁₂, (male Btot₁₂, and male and female 5CPtot expressed in kcal/day) were no more significantly different from those of healthy subjects. However, to reflect PA level more objectively, 5CPtot scores ought to be expressed in kcal/day/kg, as will be discussed further.

The increase of PA was maintained up to the fifth year post-TP. Mean Btot₆₀ scores were 6.3 $\pm$ 2.1 and 5.4 $\pm$ 2.1, which represent an increase of 7 and 10% as compared with baseline in males and females, respectively. Mean 5CPtot₆₀ scores were 35.6 $\pm$ 3.69 and 34.5 $\pm$ 3.02 kcal/day/kg, a 7 and 6% increase in males and females, respectively.

Table 4 shows the mean Baecke ($\pm$ SD) sub-scores at *t*₀, *t*₁₂ and *t*₆₀. Mean Bsport and Bleisure sub-scores increased significantly 1 and 5 years after TP, whereas Boccup remained virtually unchanged. At *t*₀, only 11 out of the 32 patients had an occupation. After TP, the employment rate remained exactly the same.

Table 5 shows the Five-City Project mean ($\pm$ SD) sub-scores at *t*₀, *t*₁₂ and *t*₆₀. One year after TP, the 28 remaining patients spent significantly less time sleeping or resting. At *t*₁₂ and *t*₆₀, our patients spent significantly more time at moderate and hard intensity PA as compared with the pre-TP period.

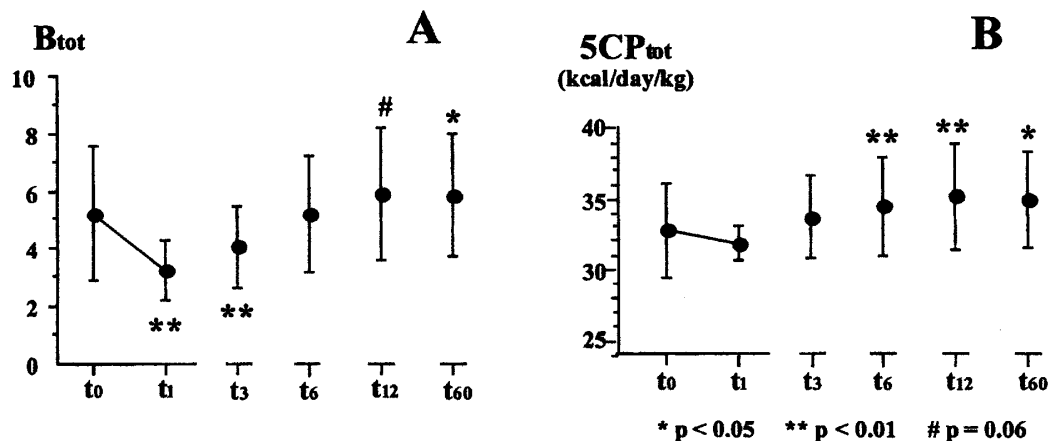


Fig. 2. Evolution of total PA scores (Btot and 5Cptot scores, mean $\pm$ SD) after TP. Significance levels for comparisons of post-TP mean scores versus baseline values (t_0) are indicated. At 1 month after TP (t_1), both mean PA scores decreased compared with t_0 . Later on, a gradual increase of PA level in graft recipients was observed; it became statistically significant at t_{12} for the Btot and at t_6 for the 5Cptot scores.

Table 4. Baecke sub-scores before, 1 year and 5 years post-TP^a

Baecke sub-scores (mean $\pm$ SD)	before TP t_0 (n=18)	1 year post-TP t_{12} (n=18)	5 years post-TP t_{60} (n=18)
Bsport	1.8 $\pm$ 1.0	2.1 $\pm$ 1.2 ^a	2.2 $\pm$ 1.1 ^b
Bleisure	2.5 $\pm$ 0.8	2.9 $\pm$ 0.8 ^c	2.7 $\pm$ 0.8 ^a
Boccup	0.9 $\pm$ 1.4	1.1 $\pm$ 1.4	0.9 $\pm$ 1.4

^aP=0.07. Analysis was made for the 18 patients who have been re-evaluated after a 60 month follow-up.

^bP<0.05; ^cP<0.01.

Table 5. Five-City Project sub-scores (h/week) before, 1 year and 5 years post TP^a

5-CP sub-scores	Before TP t_0 (n=18) (mean $\pm$ SD)	1 year post-TP t_{12} (n=18) (mean $\pm$ SD)	5 years post-TP t_{60} (n=18) (mean $\pm$ SD)
Rest	71.4 $\pm$ 13.0	65.6 $\pm$ 12.8 ^b	69.1 $\pm$ 12.0
Light	89.8 $\pm$ 13.0	90.1 $\pm$ 11.3	88.5 $\pm$ 12.4
Mod	6.1 $\pm$ 8.1	11.4 $\pm$ 8.3 ^c	9.3 $\pm$ 7.2 ^a
Hard	0	0.4 $\pm$ 1.3 ^a	0.8 $\pm$ 1.6 ^b
VHard	0	0.08 $\pm$ 0.4	0.08 $\pm$ 0.35

^aP=0.07. Analysis was made for the 18 patients who have been re-evaluated after a 60 month follow-up.

^bP<0.05; ^cP<0.01.

Discussion

Mean PA levels, measured by two distinct questionnaires, in 32 Belgian uraemic patients candidates for a renal TP were significantly reduced, as compared with those of healthy subjects. Qualitative analysis showed that uraemic subjects behave like elderly healthy controls avoiding strenuous activities. After TP, PA level increased significantly to reach a plateau within 1 year, with no gender difference. Five years after TP, mean PA level remained significantly increased compared

with pre-TP values, although a small reduction in mean PA level was observed. Despite the absence of a structured post-TP exercise programme, most patients spontaneously increased their PA level by $\sim$ 30% during the first year following TP. This observation is probably consistent with a better quality of life provided by TP.

A significant progressive weight gain was demonstrated in all subjects after TP; it was already present at t_6 and remained approximately stable later on. At t_{12} , it averaged 10% in males and 9% in females, as compared with t_0 , while their respective pre-TP mean BMI were within the normal range. A similar post-TP BMI increase was also observed by Gallagher-Lepak as soon as 4 months after TP [3], which has been attributed to an increase in fat mass. This observation emphasizes that, if PA levels have to be monitored after TP, PA scores that are normalized for body weight (and thus expressed in kcal/day/kg) should be used, as we did with the Five-City Project.

Patients' PA was retrospectively assessed after they had been admitted for TP, making the questionnaire method of analysis the only one possible. The reliability of PA level assessment by questionnaires has been widely discussed [17]. Several well known questionnaires, including those used here, are certainly considered as valid and reliable [16,17]. The Baecke and the Five-City Project questionnaires question all types of PA: occupation, leisure time and sports. They were used together here since the information they allow us to collect are complementary: the Baecke allows a subjective recall of PA classified according to their nature (occupational, leisure, sports) while the Five-City Project gives a more objective and quantitative estimation of PA classified according to their intensities (rest, light, moderate, etc.). Although the Baecke questionnaire is commonly used and easy to administer, the subjective items it includes (i.e. 'after working I am tired' or 'during leisure time I watch television',

for which subjects have to score on a 5-point Likert scale ranging from 'never' to 'always') probably leads to a more subjective, psychophysical, PA level assessment. This assumption is further supported by the greater dispersion of the Btot values: the variation coefficient calculated at t_0 was 44.5% for Btot whereas it only reached 9.8% for 5Cptot. Both questionnaires were also chosen since they could be filled in easily within 30 min. The fact that total PA scores obtained with both questionnaires significantly correlate suggests that the PA assessment methodology in this study is valid.

If PA level has to be objectively quantified, the Five-City Project should be preferred since it constitutes in itself a rate of energy expenditure measurement. The fact that uraemic patients have to spend an average time undergoing HD of 12 h/week might be responsible for a significant reduction in the total PA score. The re-calculation of the mean 5Cptot at t_0 after considering HD as a light PA (1.5 MET) instead of rest (1 MET) shows that pre-TP 5Cptot remains significantly reduced in males and females, as compared with healthy controls [14]. This suggests that uraemic patients have a significant reduction of their mean total PA level, probably in direct relation to their health status. Moreover, a shift from very hard and light intensity towards rest and sleep PA is observed in our patients, while mean time spent at hard and moderate intensity PA is not affected (Table 3). In this respect, HD patients behave like elderly subjects who are generally less active and avoid more strenuous PA.

Before TP, mean PA level of uraemic patients was significantly reduced compared with that of healthy subjects (Table 2). The PA level of the average dialysis patient is probably even affected to a greater extent, as suggested by others: transplant candidates are less inactive than patients who are not [6,7,18].

Immediately after TP, a decrease of mean PA level measured with the Baecke questionnaire is observed. Within 6 months, the PA level reached the pre-TP level again. At t_{12} and t_{60} , mean Btot scores were significantly higher compared with pre-TP values. The initial decrease can be accounted for directly by the immediate post-surgery recovery and the occurrence of acute graft rejections or other medical complications in some patients.

Overall PA level evolution, estimated with the Five-City Project, was similar. However, it increased sooner after TP (Figure 2b). At t_3 , mean 5Cptot was already higher than that observed at t_0 , although the difference was not significant. At t_6 , the difference became significant and it was maximal at t_{12} . It must be noted that the minimum PA score on the Five-City Project questionnaire is 24 kcal/day/kg, which corresponds to the value that would be recorded if a subject spent a whole week totally inactive (sleeping, for instance). Thus, with the zero of the 5Cptot scale being 24 kcal/day/kg, the relative 8 and 7% increases calculated at t_{12} for males and females, respectively, correspond to actual re-calculated increases of 31 and 27% obtained by

subtracting 24 kcal/day/kg from the values shown in Figure 2b.

In the fifth year after TP, mean PA level remained significantly higher compared with baseline values. The actual re-calculated relative increase was 25 and 22% in males and females, respectively. This small decrease in PA level observed between t_{12} and t_{60} may be consistent with the physiological reduction of PA level that occurs with aging in healthy subjects in their forties over such a 5-year period.

Do HD patients recover a normal PA level after TP? Although the increase in PA level observed after TP is partly due to the fact that graft recipients did not spend 12 h/week on dialysis any longer, a more qualitative analysis of t_0 and t_{12} Five-City Project sub-scores raised interesting issues (Table 5): at t_{12} , patients spent significantly less time sleeping or resting compared with t_0 . They spend on average 5.5 h/week less sleeping or resting, which is only approximately half the amount of time dedicated to dialysis before TP. In other words, dialysis interruption alone can only partially explain the increase of mean PA level observed in our patients. Further analysis shows that, while the sub-score corresponding to light PA (Light₁₂) remained unchanged, patients replaced most of their pre-TP dialysis time with mainly moderate intensity PA and also by a few hard intensity PAs (Table 5). Hard activities reported by the subjects consisted of intense household tasks, gardening, home renovation and sports. At t_{12} , one subject even reported 1.5 h/week of very hard sport participation. At t_{12} , the mean significant total PA increase, reflected by the mean Btot increase, was mainly explained by a more extensive participation in moderate leisure and sports type of PA since employment rate remained the same after TP.

Hence, our data showed that TP not only makes 12 extra hours per week available for light activities, but also seems to provide most subjects with a healthier status that allows participation in moderate and hard intensity PA. These observations are thus consistent with a better quality of life that accompanies successful TP, although total PA level probably remains inferior to that of healthy subjects since the low employment rate (33%) was not modified after TP in this study.

Several authors evaluated different aspects reflecting quality of life after TP: health-related fitness, functional capacity, physical working capacity [3,19–21]. Recently, Dew *et al.* [22] reviewed 218 independent studies focusing on quality of life after TP. They concluded that most studies showed significant post-TP improvements in functional indices of quality of life as PA level. However, most studies also showed that in general, graft recipients did not recover completely normal physical functioning after TP.

To our knowledge, only Gallagher-Lepak *et al.* have assessed PA level before and after renal TP using the Human Activity Profile [3]. They monitored self-reported activity level in nine patients before TP, and 6 weeks and 16 weeks after TP, and found that a significant increase in PA level was observed at 16

weeks. Our longer follow-up study, which included subjects to whom no rehabilitation programme was proposed, evaluates more quantitatively the long-term spontaneous PA level increase after TP. In some cases, organ transplant recipients are even capable of near-normal or even higher levels of physical functioning as compared with controls, as demonstrated by athletes who participated in the 1996 U.S. Transplant Games [19]. One must however keep in mind that ESRD patients present a significant weakening of cardiovascular and locomotor system as a direct consequence of renal failure and inactivity. Moreover, after TP, immunosuppressive drugs have a direct weakening effect on muscles [11] and bones [12]. This led some authors to hypothesize that an excessive PA performed immediately after TP might be responsible for the occurrence of epiphyseal impactions [23]. Patients should therefore be precisely advised to minimize the risk of locomotor injury post-TP. This could be achieved by systematically proposing exercise programmes individually tailored to the needs and condition of each patient. Such programmes have indeed been successfully applied to haemodialysis patients [24]. Shortly after TP, such programmes should also favour individual aerobic exercise of large muscles without excessive mechanical strains on bones and joints (stationary or outdoor cycling, swimming or walking). Miller *et al.* showed that such a supervised aerobic exercise regimen proposed to 10 selected patients after renal TP led to a 90% exercise capacity improvement after only 5.5 weeks [9]. Most of their patients (7/10) continued exercising regularly after the supervised programme was completed and they achieved normal exercise capacity within 8 weeks of TP. Later on, after normal physical capacity has been recovered, more intense sports participation (e.g. jogging, ball sports, etc.) may be considered.

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The Role of Exercise in the Treatment of Fibromyalgia: An Overview

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Most agree that exercise should be part of the comprehensive therapy for most individuals with fibromyalgia (FM), but a specific, positive effect of exercise on the primary symptom of FM—pain—has not been demonstrated. Individuals with FM seem as “trainable” as healthy subjects are; any fitness gain should lead to improved physical function. Low to moderate endurance training could also improve muscle oxygenation and local metabolism, making patients less prone to muscle injuries. Exercise has positive effects on patients with FM, many of which could be explained by a change in attitude of the patients, particularly toward physical activity, rather than by any specific neurohormonal or muscular effect. Unless the patient is found unfit, the main goal of the exercise program should not be cardiovascular reconditioning. Low-intensity, low-impact cardiovascular workouts and warm-water pool-based exercises and stretching should be combined. Education about the disease is an important element of the program. Exercise-group sessions can also be useful.

Key Words: physical fitness, pain, fitness testing

Key Points:

- In fibromyalgia, well-conducted exercise programs provide overall improvement, although a relationship to specific pain alleviation has yet to be established.
- Individuals with fibromyalgia might not be as unfit as generally thought.
- Most fitness-testing procedures have not been validated in patients with pain.
- Exercise should be combined with education in the comprehensive management of patients with fibromyalgia.

Introduction

Fibromyalgia (FM) is a complex condition that has gained acceptance by the World Health Organization (WHO) as a diagnosis and is listed in the classification of chronic-pain syndromes published by the International Association for the Study of Pain.¹

In the United States alone, there are approximately 6 million individuals with FM, making it the third most prevalent rheumatological condition in this country.² This means that up to 20% of patients attending physical medicine and rheumatology clinics³ present with this condition and that its prevalence reaches about 2%.⁴

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Although a general agreement exists about the American College of Rheumatology classification criteria for FM that are now widely used,⁵ many questions concerning the pathogenesis of this complex condition still remain unanswered.

Patient education and reassurance about the nature of the disease, as well as medications and exercise, are generally considered the most important aspects of treatment. Although many authors report overall improvement from well-conducted exercise programs in patients with FM,⁶⁻¹¹ the mechanisms of action of this treatment modality and its effects on pain still remain unclear. Moreover, the fact that patients with FM often report pain worsening during and after exercise¹²⁻¹⁵ seems to conflict with the fact that exercise is generally prescribed.

The purpose of this article is to review data on exercise and FM to try to clarify some conflicting observations and to provide the reader with practical knowledge that will be helpful in the rehabilitation of such patients.

Reasons to Prescribe Exercise to Patients With Fibromyalgia

Patients with FM are often considered physically less active than the norm^{13,16} and unfit.¹⁶⁻¹⁹ Because fitness is a major determinant of physical capacity,²⁰ reconditioning unfit individuals should improve their function in activities of daily life. Likewise, it has been postulated that the muscles of unfit individuals with FM are more prone to microscopic injury, leading to a phenomenon like delayed-onset muscle soreness.²¹ Local excessive muscular hypoxia or accumulation of metabolites might also be a cause of muscle pain in less-active and -fit subjects with FM, and improved local circulation induced by endurance training should help alleviate muscle pain.^{19,22} On the other hand, several authors have found cardiorespiratory endurance (ie, aerobic power) of individuals with FM to be normal.^{14,15,23,24} To help clarify these apparently conflicting observations, some fundamentals of fitness evaluation must be briefly recalled and discussed.

Fitness is a multifactorial construct that includes several health-related components: cardiorespiratory endurance (CRE), or aerobic power; muscle strength and endurance; flexibility (range of motion); and body composition.²⁵ CRE is generally considered the most fundamental component, but each component can be independently estimated by testing procedures that have been validated in healthy subjects. Although many authors have used such testing methods to evaluate patients with FM, the validity of CRE-, strength-, and flexibility-testing protocols requiring maximal effort should be questioned in patients with pain. For instance, the lower peak-oxygen uptakes, muscular strength,^{23,26-28} or flexibility²⁸ observed by many authors in patients with FM might indicate that such subjects perform only submaximally in relation to several factors such as pain, fear of pain wors-

ening, hypervigilance phenomenon,²⁹ higher rate of perceived exertion,^{13,23,24,30} and poor tolerance to effort in general. Hence, probably neither true maximal CRE nor maximal strength and flexibility can be reliably estimated in most patients with pain. Finally, it must be noted that almost all studies that employed submaximal testing procedures, such as the Astrand 6-minute cycle-ergometer test,³¹ found normal CRE in FM.^{14,15,23} Thus, CRE might still be within normal range in patients with FM, as a group. In such cases, the main goal of exercise programs should thus not be physical reconditioning itself. Rather, the emphasis should be on improving exercise tolerance and decreasing muscle tensions, which can be achieved, for instance, by lower cardiovascular intensity or pool-based or stretching exercises.

McCain⁷ suggests that sufficiently vigorous exercise could elicit an exercise-induced analgesia in FM through a higher level of circulating beta-endorphins or other hormones as described by Janal.³² Not only have Padawer et al³³ shown that Janal's observations might be artifactual but also, in our opinion, such a mechanism could still induce only short-term pain alleviation.

Finally, as in healthy exercising subjects, a general positive effect of exercise on mental status and mood could reasonably be expected in patients with FM. Such an effect would not be specific but could nevertheless be more pronounced in those who are more distressed and sedentary. Moreover, exercise interventions are usually combined with education on the nature of FM, advice on coping strategies, and encouragement to be more physically active. In this way, these approaches should also be beneficial through their underlying behavioral-therapy component, because they will probably help reduce fear-avoidance behavior as described by Vlaeyen et al.³⁴

Do Patients With Fibromyalgia Benefit From Exercise Programs?

Many exercise modalities have been evaluated, such as strenuous cardiovascular and flexibility training⁷; cardiac rehabilitation-type exercises³⁵; light low-impact aerobic dance²²; walking^{8,36}; combinations of cardiovascular, flexibility, and strengthening workouts⁹; jogging, walking, cycling, and swimming³⁷; pool- and land-based exercises³⁸; and strength training alone.³⁹ Several authors have shown that if education (FM self-management courses emphasizing coping strategies, behavioral modifications, and encouragement of physical activity) is combined with physical training, the benefits in terms of psychological well-being, as well as in pain symptoms, were more pronounced and long lasting.^{11,40-43} A group-treatment approach, which includes discussions on strategies to improve physical fitness, also showed promising results,⁴⁰ which is in agreement with our personal experience.

In general, patients with FM are able to improve the fitness components that have been trained during the program, suggesting normal cardiovascular and neuromuscular adaptation to exercise.^{9,22} Most programs seem

to provide patients with an overall improvement in well-being and mental status, indicating better quality of life. This can be observed independently of pain alleviation, as recently reported by Ramsay et al.⁴⁴ Nevertheless, the effects of exercise programs on pain itself are often disappointing,^{7,8,22,35} even if some encouraging results have been obtained in several trials.^{9,37,38} It must be noted that many studies provide minimal statistics, which is largely because of the relatively small number of patients included and the large variance of pain-outcome measures. Hence, the absence of positive results should probably often be considered inconclusive rather than negative, because type II errors cannot be excluded. Finally, in most exercise-based interventions, patients also often benefit from education, medications, and, sometimes, other treatment modalities, rendering any exercise-specific effect difficult, if not impossible, to distinguish from other effects.

Adverse Effects of Exercise in Fibromyalgia

Many authors have reported a worsening of pain after initiation of an exercise program that might last for up to 3 months.⁷ If the exercise intensity is too high and prolonged, not only will it enhance pain but it might also eventually have an adverse effect on function.⁸ Such adverse effects are probably best explained by an excessive neuroendocrine response associated with excessively strenuous exercise. Exercise type also matters. Most authors agree that non-weight-bearing, concentric- or isometric- rather than eccentric-type exercises are preferable to avoid exercise-induced pain in FM.

Many of the authors who conducted clinical trials that included exercise programs for patients with FM have mentioned that they encountered a problem with compliance. A dropout rate of close to 30% has been found in several studies. Such a phenomenon might be explained by insufficient details provided about the reasons for exercising or inadequate choice of workout intensity or type.

Practical Guidelines for Exercise Prescription in Patients With Fibromyalgia

Although the fitness of most patients with FM might be normal, there are large individual differences. Cardiorespiratory endurance should thus be systematically evaluated before initiating any exercise program. This is preferably done using a submaximal testing procedure as previously discussed. This evaluation is helpful in defining the goals of the program according to the measured fitness level of each patient. It will also be useful in monitoring the progress of and motivating the patients, because they will almost certainly gain in fitness as the program proceeds. We use a

multistage cycle-ergometer fitness test that also allows for assessment of the rate of perceived exertion,²⁴ which is often elevated in patients with FM.

Outcome measures, reflecting pain and overall well-being, should be monitored during the program. A more specific tool such as the Fibromyalgia Impact Questionnaire⁴⁵ could be particularly relevant.

A clear and coherent rationale on the reasons that exercise is useful should be given to patients before they enter the program and should be regularly recalled throughout the program.

The exercise intervention should include a minimum of 2 or 3 supervised 30- to 45-minute sessions per week. More frequent, shorter sessions could also be implemented. The exercise program should be undertaken for a minimum of 3 months in order to obtain the desired effects, as well as a lasting behavioral change in terms of habitual physical activity.

Unless the patient is found to be unfit, the main goal of the exercise program should not be cardiovascular reconditioning. Rather, low-intensity cardiovascular workouts (eg, cycling, walking), warm-water pool-based exercises, and stretching should ideally be combined. At the start of the program, exercise intensity should not raise heart rate above 50% of heart-rate reserve, nor should the perceived exertion score rise higher than 5 on the 10-point Borg scale in order to avoid postexertional pain and excessive neurohormonal reaction. Exercises with high eccentric components, such as jogging and ball games, should be avoided for the same reasons.

As has been discussed, education on FM self-management favoring coping strategies and behavioral changes, particularly in terms of exercise participation, should be combined with the exercise component of the program. Our personal experience agrees with the findings of Bennett et al,⁴⁰ who found that group interventions can also be useful in FM. If such methods are implemented, however, patients should always be able to control their exercise intensity.

It should always be borne in mind that alleviating pain and improving quality of life, not solely improving fitness, should be the ultimate goals of any program.

Conclusions

A clear, specific, positive effect of exercise on the primary symptom of FM, namely, pain, has not yet been demonstrated. Nevertheless, most authors agree that exercise should form part of the comprehensive therapeutic program of most patients with FM.

Many reasons have been advocated for which patients with FM should exercise. Although patients with FM might not be as unfit as generally thought, they are as “trainable” as healthy subjects are. Hence, any gain in fitness should lead to improvements in physical function, even in subjects with near-normal fitness. Low to moderate endurance training could also

improve muscle oxygenation and metabolism, making such patients less prone to microscopic muscle injuries that could cause postexertional pain.

Many authors have reported that exercise generates positive effects on the psychological state of patients with FM in terms of well being, self-esteem, self-efficacy, and a decrease of anxiety and depression, which ultimately results in a better quality of life. Many of the positive effects of exercise could be explained by a change in attitude of the patients, particularly with regard to physical activity in daily life, rather than by any hypothetical specific central (neurohormonal) or peripheral (muscular) effect. During exercise programs, patients are gradually exposed to all sorts of physical activities that they usually fear and avoid. If the program is well designed, patients are reassured by finding that they are able to exercise without any major increase in pain. As they also progressively improve their physical capacity and mental state, the overall gain in terms of quality of life might be important. Hence, even in the absence of a clear, specific pain-alleviation effect in FM, exercise is always a winner.

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Cardiorespiratory Fitness, Physical Activity Level, and Chronic Pain: Are Men More Affected Than Women?

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Abstract

Objective: To evaluate the cardiorespiratory endurance (CRE) and physical activity level of patients with chronic pain compared with healthy subjects.

Design and Subjects: Cross-sectional study, with a consecutive sample of 55 patients with chronic pain (20 men, 35 women). Comparison of CRE and physical activity indices obtained in patients with data available in the literature for age-matched healthy subjects.

Setting: A multidisciplinary pain center in a city of more than 1,000,000 inhabitants.

Outcome Measures: A physical working capacity index ($PWC_{65\%/kg}$) and physical activity level scores and subscores obtained with two questionnaires (the Baecke and the Five-City Project questionnaires).

Results: The physiological gender difference in CRE indices that characterizes healthy subjects was not observed in patients with chronic pain. When compared with values previously obtained in controls, male patients presented with a very significant 34% reduction in $PWC_{65\%/kg}$. The 17% reduction found in women hardly reached significance level. The Baecke total physical activity score was significantly higher in female than in male patients, a finding not observed in healthy controls. There was no significant difference between male and female patients in the Five-City Project total physical activity score expressed in kilocalories per day per kilogram (i.e., normalized for body weight), although data from the literature show that healthy men present with a significantly higher level of physical activity compared with healthy women.

Conclusions: Data on CRE and the physical activity level of patients with chronic pain obtained in this study show that chronic pain may have a greater impact on male than female patients. Sociocultural factors are probably at the origin of this phenomenon.

Key Words: Cardiorespiratory endurance—Chronic pain—Cycle ergometer test—Fitness evaluation—Physical activity.

Many studies have investigated the impact of chronic pain states on patients' functional capacities.^{1–3} Several of these studies focused on indicators of cardiorespiratory endurance (CRE),^{2–5} and all reported a significant reduction in CRE in most patients with chronic pain. To account for the reduced CRE, investigators usually hy-

pothesize that the level of physical activity is reduced in relation to job loss, rest prescribed by physicians, or learned activity avoidance behaviors caused by actual enhancement of pain by activity or simply to the fear of inducing activity-related pain. Some investigators have termed this condition a "deconditioning syndrome,"¹ whereas others call it a "disuse syndrome."⁶ However, the hypothetical relation between the reduction in CRE and reduced physical activity as a consequence of the chronic pain state has, to our knowledge, never been assessed directly in patients with chronic pain.

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In previous studies, we observed in two separate cohorts of patients with chronic pain that CRE, as measured by a submaximal cycle ergometer test, was significantly reduced only in men when compared with age- and sex-matched controls.^{4,5} It was hypothesized that sociocultural factors could possibly account for a greater level of inactivity in men with chronic pain than in women. Indeed, retrospectively, it was found that more male patients had a physically demanding occupation, and more male patients lost their use as a consequence of chronic pain. Moreover, at home, women seemed to be more physically active than men as they were more often responsible for household tasks and child care.

The aim of the current study was to test this hypothesis directly by measuring CRE using a submaximal multi-stage cycle ergometer test and assessing the level of physical activity by two reliable and validated physical activity questionnaires in a cohort of 55 patients with chronic pain.

MATERIALS AND METHODS

Subjects

Fifty-five consecutive patients with chronic pain (20 men, 35 women) were included in this study after initial clinical evaluation, before any assessment of physical capacity was conducted or any therapeutic program initiated. All patients had been referred to the Chronic Pain Unit of the Multidisciplinary Pain Center of the Cliniques Universitaires St-Luc, a university hospital in Brussels, Belgium (a city with more than 1,000,000 inhabitants). Patients were referred by general practitioners or specialists (e.g., orthopedic surgeons, rheumatologists) of the region. All patients participating in the study gave their informed consent, and the rules of the Ethics Committee of the Faculty of Medicine (Université catholique de Louvain) were followed.

According to the International Association for the Study of Pain⁷ and classification of chronic pain syndromes, and on the basis of available clinical and laboratory data, the patient group was composed of 20 male and 35 female patients: 30 (10 men/20 women) patients with chronic low back pain with or without sciatica, 13 (5 men/8 women) with fibromyalgia syndromes, and 12 (5 men/7 women) with miscellaneous other chronic musculoskeletal pain conditions such as cervical or dorsal pain, neuropathic pain often secondary to surgery, and headache.

The mean age of the patients was 44 ± 9.3 years, and they had previously undergone an average of 1.0 surgical procedures related to their pain. All patients had suffered for more than 1 year, most for several years, when the study was initiated.

CRE assessment

A variety of testing procedures is used to assess fitness in patients with pain. Some methods include exhaustive evaluation of all major components of fitness (i.e., strength, flexibility, coordination, and CRE).¹ However, most testing protocols used in studies of patients with pain have been validated in healthy subjects only. Such protocols often require maximal effort and sophisticated as well as expensive equipment. Hence, the validity and reliability of many fitness testing procedures (maximum oxygen uptake [$\dot{V}O_{2\max}$] evaluation, maximal back extensor strength, flexibility, etc.) may certainly be questioned in the context of the evaluation of patients with chronic pain, since most maximal protocols tend to be rather symptom-limited and may thus underestimate the patients' true physical capacities.⁸

CRE is generally considered to be the most fundamental component of fitness.^{8,9} Moreover, it can be reliably assessed by submaximal testing protocols not requiring sophisticated and expensive equipment (gas analyzers, isokinetic torque meters, etc.). It would thus seem preferable to focus only on CRE when assessing the fitness of untrained subjects, particularly of patients with chronic pain.⁸

Some submaximal protocols allow calculation of several well-known submaximal physical working capacity indexes (PWC_{170} , $PWC_{75\%}$, etc.) that are considered as reliable indicators of CRE.^{2,10,11}

In this study, only the most fundamental component of fitness (i.e., CRE) was evaluated. A submaximal working capacity index that has been shown to be a valid and reliable index of CRE in patients with chronic pain⁴ was obtained by means of a simple submaximal cycle ergometer test suitable for routine clinical use.

Cycle ergometer test

The methodology of this test has been described in detail previously.⁵ The test is conducted on a Monark cycle ergometer (model 818E, Vansbro, Sweden). After a brief warm-up period of a few minutes during which the subject gets familiar with the imposed pedaling cadence (60 rpm), the subject is asked to perform several 2-minute stages of gradually increasing intensity. Briefly, starting from a work intensity (power) of 25 W, the power is increased in a stepwise manner every 2 minutes by 25 W until the patient's heart rate (HR) reaches a value corresponding to 65% of his or her HR reserve ($HR_{65\%}$) or more, according to Karvonen's formula, in which resting HR is assumed to be 80 beats/min for all patients. Indeed, while the resting HR should theoretically be easy to measure, it may vary considerably between and within subjects and especially in patients

with chronic pain who are habitually more anxious during the period immediately preceding an exertion test and often use medication affecting resting HR (tricyclic antidepressants, β -adrenergic antagonists, etc.). Together, these factors make resting HR measurements unreliable. As a consequence, if the $PWC_{65\%}/kg$ is used as an index to monitor improvement in CRE, the variability of any measured resting HR may lead to an error in the estimation of the improvement made by the patients. To avoid this potential problem, a fixed resting HR value of 80 beats/min was selected to be used for the calculation of the $PWC_{65\%}/kg$ for all subjects in this study. This value was chosen because it was the average resting HR previously obtained from a large number of patients (>50) with chronic pain whose resting HR was measured at the end of a 2-minute period spent sitting quietly (unpublished results). Although 80 beats/min seems to correspond to the average resting HR of such patients, it is obvious that this approximation may lead to a considerable margin of error in the estimation of the resting HR in some subjects. Most patients achieve three or four stages, and some may achieve more depending on their level of fitness.

During the test, the HR of the patient is monitored by a HR meter (Polar, Kempele, Finland). The HR corresponding to the steady state at the end of each stage is recorded as well as the corresponding powers (25, 50, 75, 100 Watts, etc.).

Calculation of the fitness index ($PWC_{65\%}/kg$)

The power or work capacity at $HR_{65\%}$, $PWC_{65\%}$, is obtained by interpolation of the power (watts) for $HR_{65\%}$ on the HR-versus-power linear relation calculated from the data collected during the test. The fitness index ($W_{65\%}/kg$) is finally obtained by normalizing $PWC_{65\%}$ for body weight (kilograms) of the subject and is expressed in watts per kilogram (Fig. 1). This index may be considered as the power, expressed in watts per kilogram of body weight, that the subject would generate on a cycle ergometer if he or she exercised in a steady state at a relative work intensity corresponding to 65% of his or her HR reserve. The $PWC_{65\%}/kg$ is thus the equivalent of several well-known indexes such as the PWC_{170} , PWC_{150} , and PWC_{160} previously used by investigators to evaluate the CRE of patients with chronic pain,^{2,10,12,13} except that the $PWC_{65\%}/kg$ is calculated for the same relative work intensity (corresponding to 65% of the HR reserve of the subject according to age) instead of the same absolute value of HR (150, 160, 170 beats/min, etc.). This methodology is preferable in groups including subjects with a wide range of ages.^{4,11}

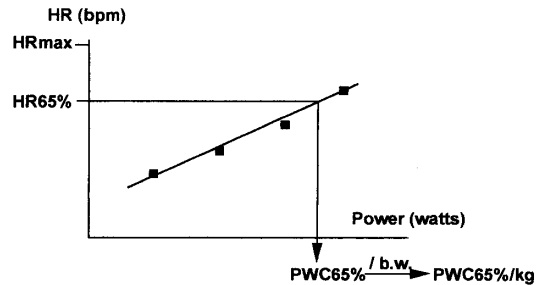


FIG 1. The cardiorespiratory index ($PWC_{65\%}/kg$) is based on the linear relation of heart rate (HR in beats/min) versus intensity of exercise (power in watts) on a cycle ergometer. The HR values are measured at the end of each of the four stages of the cycle ergometer test. $PWC_{65\%}$ is computed by interpolation (i.e., the power corresponding to a HR of 65% of the HR reserve [$HR_{65\%}$]). Finally, the cardiorespiratory endurance index ($PWC_{65\%}/kg$) is obtained by normalization for body weight (b.w. in kilograms).

Evaluation of physical activity

Numerous studies have been conducted to evaluate the accuracy (validity and reliability) of questionnaires as tools to assess the level of physical activity¹⁴⁻¹⁶ and have found this technique to be satisfactory.^{17,18} More objective and accurate methods such as respiratory chambers and double-labeled water methods are hardly applicable in routine clinical use or epidemiologic studies because of their cost and complexity and the fact that they may influence the subject's behavior. The use of such methods is therefore generally limited to validation studies of other activity assessment tools such as questionnaires.¹⁴

The choice of the questionnaire depends on several factors, including the population studied, the type of physical activity that should be assessed, the time available for the interview, and, possibly, interviewer skills. We chose two questionnaires that are generally presented as valid and reliable for population-based studies,¹⁴⁻¹⁶ that could both be administered in less than 30 minutes and that covered all types of physical activity (occupation, leisure, sports, etc.). The Baecke self-administered¹⁹ questionnaire and the Five-City Project questionnaire^{20,21} satisfied these criteria and were thus used in this study after translation into French. For the Baecke questionnaire, the fact that normal data for European healthy subjects are available in the literature was also considered.

All patients were evaluated by the same well-trained observer.

The Baecke self-administered habitual physical activity questionnaire

The Baecke questionnaire includes 19 questions addressing the three main types of common physical activity (i.e., occupation, sports, and nonsports leisure activity). For each

question, the subject is asked to score his answer on a five-point Likert scale ranging from “never” to “always” or “very often.” In addition, for the two most frequently reported sports, the subject is asked to report the number of months per year and hours per week of participation. Three indexes are calculated on the basis of the scores given by the subject: a Work index, a Sports index, and a Nonsports leisure index. The total Baecke score is obtained simply by summing these three indexes.

In the current study, the Baecke questionnaire was self-administered, but active help of the observer was provided when necessary. We used the following abbreviations: Boccup for Work index, Bsport for the Sports index, Bleisure for the Nonsports leisure index, and Btot for the total Baecke score.

The Five-City Project 7-day recall physical activity questionnaire

With the Five-City Project questionnaire, subjects are asked about their activities of the previous week after classifying them according to intensity (energy expenditure rate). Knowing that one MET is defined as the energy expenditure rate (work intensity) corresponding to sitting quietly and that it approximates the resting metabolic rate (approximately 1 kcal/kg/h),^{20,22} the total amount of time (hours) spent during the previous week (workdays and weekend) in sleeping or resting (energy expenditure rate = 1 MET), and activity of light (1.5 MET), moderate (4 MET), hard (6 MET), and very hard (10 MET) intensity are recorded. These five amounts, expressed in hours per week, constitute the five Five-City Project physical activity subscores: Rest, Light, Mod, Hard, and Vhard. To allow recording and classification of some activities that were not present on the questionnaire’s list of examples, we used the Compendium of Physical Activities from Ainsworth et al.²²

The final total physical activity score (5-CPtot) is obtained by summing the five subscores multiplied by their corresponding intensity level (in METs) and dividing by 7 (7 d/wk). Thus, the 5-CPtot represents the average daily energy expenditure rate of the preceding week, expressed in kcal/d or, when normalized for body weight, expressed in kcal/d/kg. The 5-CPtot score expressed in kilocalories per day, which reflects the total daily energy expenditure of the subject, is directly related to the weight of the subject and thus tends to overestimate the actual physical activity in overweight subjects.²⁰ Hence, it may not be considered as an acceptable measure of energy expenditure in overweight populations, such as the patients in this study, who present with elevated body mass index values. Thus, to reflect the real physical activity of the subject, 5-CPtot needs to be normalized for body weight.

Statistical analysis

For all measured variables (CRE index, total physical activity scores, and corresponding subscores) mean values and SD were calculated.

To evaluate the effects of gender difference on CRE and physical activity, an ANOVA with gender as the independent factor was conducted on CRE indexes and on all physical activity scores and subscores. If there was a difference in the total physical activity scores according to gender, contrast analysis (Scheffé F test) was conducted on the physical activity subscores to evaluate which type of activity contributed most to the difference.

To compare the mean CRE indexes obtained in this study to those of other studies, Student *t* tests were used based on the available data (mean, SD, and number of subjects).

The Spearman ρ correlation coefficient was calculated to evaluate the strength of the relation between fitness ($PWC_{65\%/kg}$) and physical activity (respectively Btot and 5-CPtot) and between both questionnaires scores.

RESULTS

With a mean weight of 84 ± 18.0 kg and 67 ± 13.3 kg and mean height of 1.74 ± 0.05 m and 1.64 ± 0.07 m for men and women, respectively, the patients with chronic pain in this study, especially the men, may be considered as moderately overweight. Indeed, according to Jaquier,²³ the mean body mass index of 27.7 kg/m² obtained in male patients is consistent with grade 1 obesity. With a body mass index value of 24.9 kg/m², women are at the upper limit of the desirable range.

CRE of patients with chronic pain

The mean and SD of the fitness index ($PWC_{65\%/kg}$) obtained in patients, as well as in 34 healthy control subjects,⁵ are presented in Table 1.

Previously reported control values of $PWC_{65\%/kg}$ ⁵ were significantly higher in men than women ($F = 16.99$; $p = 0.0001$), which is consistent with the

TABLE 1. Fitness as measured by the $PWC_{65\%/kg}$ in patients with chronic pain and healthy subjects

Cardiorespiratory endurance index $PWC_{65\%/kg}$ (watts/kg)	Chronic pain patients (mean $\pm$ SD)	Healthy subjects* (mean $\pm$ SD)
Males	$1.59 \pm 0.48^\dagger$ n = 19	$2.42 \pm 0.68^\ddagger$ n = 17
Females	$1.38 \pm 0.38^\dagger$ n = 34	$1.66 \pm 0.46^\ddagger$ n = 17

*From Nielens & Plaghki, 1994.

$^\dagger p = 0.09$.

$^\ddagger p = 0.0001$.

well-known fact that, in the healthy population, such CRE indices are higher in men.²⁴ In the patients in this study, the physiologic gender difference in PWC_{65%}/kg was not present ($F = 2.99$; $p = 0.09$) because of a greater reduction in PWC_{65%}/kg, which reached 34% in men and only 17% in women, in comparison with values for healthy subjects included in Table 1.

Physical activity level as assessed by the Baecke Questionnaire

Total physical activity scores and subscore indexes obtained with the Baecke questionnaire in patients with chronic pain are presented in Table 2. The Baecke total physical activity score (Btot) was significantly higher in female than in male patients ($F = 4.1$; $p = 0.049$). This was confirmed by a repeated-measures ANOVA on the three subscores with gender as the independent factor.

Contrast analysis with the Scheffé post hoc test (Table 2, last column) showed that the occupation subscore (Boccup) probably contributed the most to this difference. Indeed, in the group of male patients, only 20% (4 of 20) were still at their job at the moment of physical activity evaluation as compared with 34% (12 of 35) of the female patients.

Physical activity level as assessed by the Five-City Project Questionnaire

Total physical activity scores (mean $\pm$ SD) obtained with the Five-City Project questionnaire (5-CPtot) in male and female patients are presented in Table 3, where they are expressed in kilocalories per day and kilocalories per day per kilogram. In the last column of this table, mean differences in 5-CPtot scores of men as compared with women and significance levels are also presented.

When the 5-CPtot score was expressed in kilocalories per day, the mean total physical activity level of male patients was significantly higher than that of women

TABLE 2. Baecke total physical activity score and subscores obtained in 55 patients with chronic pain

Baecke scores and sub-scores	Males (n = 20, mean $\pm$ SD)	Females (n = 35, mean $\pm$ SD)	Mean difference & significance level
Btot	4.5 $\pm$ 1.5	5.5 $\pm$ 1.8	-0.99 $p = 0.049$
Boccup	0.5 $\pm$ 0.9	1.2 $\pm$ 1.7	-0.75 $p = 0.077$
Bsport	1.6 $\pm$ 0.4	1.6 $\pm$ 0.5	0.04 $p = 0.741$
Bleisure	2.4 $\pm$ 0.7	2.7 $\pm$ 0.6	-0.26 $p = 0.158$

TABLE 3. Five-City Project total physical activity scores and subscores in chronic pain patients

Five-City Project scores and sub-scores	Males (n = 20, mean $\pm$ SD)	Females (n = 35, mean $\pm$ SD)	Mean difference & significance level
5-CPtot (kcal/day)	2905 $\pm$ 739.5	2303 $\pm$ 609.7	602.4 $p = 0.002$
5-CPtot (kcal/day/kg)	34.4 $\pm$ 4.15	34.1 $\pm$ 3.77	0.28 $p = 0.797$
Rest (hours/week)	66.9 $\pm$ 21.35	65.4 $\pm$ 14.39	1.50 $p = 0.758$
Light (hours/week)	92.9 $\pm$ 21.02	94.8 $\pm$ 14.03	-1.94 $p = 0.684$
Mod (hours/week)	7.3 $\pm$ 6.21	7.7 $\pm$ 9.18	-0.39 $p = 0.868$
Hard (hours/week)	0.9 $\pm$ 3.80	0.1 $\pm$ 0.42	0.83 $p = 0.20$
Vhard (hours/week)	0	0	0

($F = 10.6$; $p = 0.002$). However, if the 5-CPtot score was expressed in kilocalories per day per kilogram (i.e., normalized for body weight), the absolute total physical activity level of male and female patients was not significantly different ($F = 0.07$; $p = 0.797$). There were no significant differences between male and female patients in the different categories of physical activity as reflected by all Five-City Project subscores. The patients in this study did not report any very hard, and only very few hard, physical activities.

Correlation between physical activity scores and between fitness index and physical activity scores

There was a weak although significant correlation between the Btot and the 5-CPtot expressed in kilocalories per day per kilogram (Spearman $\rho = 0.32$; $p = 0.02$).

The correlations between the fitness index and both total physical activity scores were not significant (Spearman $\rho = -0.17$, $p = 0.22$ and $\rho = 0.23$, $p = 0.08$ for PWC_{65%}/kg vs Btot and vs 5-CPtot expressed in kilocalories per day per kilogram, respectively).

DISCUSSION

Many investigators have observed a reduced physical capacity in patients with chronic pain. This condition is thought to be related to a reduced level of physical activity as a direct consequence of chronic pain. In two previous studies^{4,5} involving a total of 98 patients with chronic pain, we observed that CRE, often considered as the most important component of fitness⁸ and thus of functional capacity,²⁵ was altered more in male than female patients. We thus retrospectively hypothesized that

this phenomenon was probably a result of sociocultural factors, including job loss, which seems more systematic in men.⁴ The current study, which included assessment of CRE as well as the level of physical activity in 55 patients, was conducted to test this hypothesis.

CRE in patients with chronic pain and influence of gender

It is a common clinical observation that patients with chronic pain seem generally unfit and physically inactive. Physical reconditioning is thus frequently proposed as part of the multidisciplinary treatment program.

In this study, the physiologic gender difference in CRE (Table 1) that characterizes healthy subjects^{22,24} was absent as demonstrated by the lack of a significant difference between male and female $PWC_{65\%}/kg$. As compared with the $PWC_{65\%}/kg$ values previously obtained in controls,⁵ the male patients in this study presented with a very significant 34% reduction in $PWC_{65\%}/kg$ (Student $t = 4.27$; $p < 0.01$). Although also significant (Student $t = 2.31$; $p \approx 0.02$), the 17% reduction in $PWC_{65\%}/kg$ found in women was less pronounced. Moreover, according to Gettman,²⁶ the fitness of the male patients could be described as "poor" (<1 SD from mean of the control group) and that of the women as "fair" (<0.5 SD from mean of control group). Finally, on the basis of the $PWC_{65\%}/kg$ values (calculated $PWC_{65\%}$ and corresponding $HR_{65\%}$), the $\dot{V}O_{2max}$ of the patients may be estimated roughly using the Astrand nomogram.^{9,10,24} Using this method, $\dot{V}O_{2max}$ may be estimated to be 32.9 ml/kg/min in male patients with chronic pain and 35.1 ml/kg/min in women. These values would place the male patients at approximately P20 and the females at approximately P75 according to the American College of Sports Medicine's normal values for $\dot{V}O_{2max}$.²⁴

These observations, along with the findings of other investigators who have also used CRE submaximal testing protocols,²⁷ are in agreement with those of two previous studies conducted in the same Chronic Pain Unit.^{4,5} Hence, the fact that CRE seems to be affected more in male patients with chronic pain than in female patients may have been overlooked in most studies. In fact, many studies²⁸⁻³⁰ used maximal exercise testing protocols to evaluate CRE, which may not be satisfactory in patients with chronic pain since such testing protocols, as previously discussed, tend to be symptom-limited and may thus not be valid in such patients. Moreover, many studies including CRE evaluations also focused primarily on physical reconditioning. Hence, the results of such studies are generally presented for men and women as one group,^{1,2,27,28,31} which renders recognition of any

gender effect on CRE in patients with chronic pain impossible.

Nevertheless, the hypothetical greater impact of chronic pain in male patients in terms of physical deconditioning that we have observed in our Chronic Pain Unit (in 153 patients, 68 men and 85 women, from three separate studies) should be confirmed using other CRE evaluation procedures because no general agreement exists about the most accurate (valid and reliable) CRE evaluation method in patients with chronic pain.^{3,30} Similar CRE evaluations in other countries could also be conducted to define the possible role of sociocultural factors governing the onset of physical deconditioning in such patients.

Physical activity assessment by questionnaire in patients with chronic pain

Much has been written on the issue of the validity and reliability of questionnaires. In particular, it must be stressed that most commonly used questionnaires have not been validated in patients with chronic pain.³² Hence the question of the validity and reliability of such methods remains unanswered in that context. Although the choice of questionnaires made in this study agrees with the general recommendations applicable to patients with chronic pain,³² it is obvious that any results obtained from the assessment of the level of physical activity by questionnaire in patients with chronic pain must be interpreted with caution.

In this study, the level of physical activity was assessed by two different questionnaires that are complementary: the Baecke and the Five-City Project questionnaires. The Baecke questionnaire may be considered as semiquantitative. Indeed, while it objectively evaluates the level of physical activity related to participation in sports using the Durnin and Passmore sports classification,²² physical activity related to occupation and leisure time is more subjectively self-evaluated on a five-point Likert scale leading to physical activity indexes expressed in ordinal units without reference to any physiologic variable. On the other hand, the Five-City Project questionnaire, by recording the subjects' physical activity categories, intensities, and duration, may be considered as a quantitative and more objective method because it directly leads to an energy expenditure rate estimation preferably expressed in kilocalories per day per kilogram. Although the Five City Project thus seems more objective and the Baecke more subjective, the latter is still cited in a recent review³² as a questionnaire that may be used in patients with chronic pain.

Although weak, the statistically significant positive correlation found between both questionnaire scores

(Spearman $\rho = 0.32$; $p = 0.02$) may be considered as an argument supporting their validity.

For future studies addressing the assessment of the level of physical activity in patients, direct measurement methods such as more recent models of multidirectional accelerometers, or activity recordings with a daily activity diary as used by Follick et al.³³ in patients with chronic pain, should probably be preferred. The use of a questionnaire more specifically oriented toward more sedentary subjects, such as the Modified Baecke Questionnaire,³⁴ could also be considered.

Physical activity level in patients with chronic pain

When the physical activity of patients is assessed with the Baecke questionnaire, patients of both genders seem to present with a very significant reduction in total physical activity level as compared with data for healthy subjects available from the literature.^{16,19,35} Depending on the normal values in the studies referred to, the relative reduction in the total Baecke physical activity score ranged from 45 to 41% in male patients and from 35 to 27% in female patients, with respective Z scores ranging from -2.5 to -2.1 in men and from -1.7 to -1.3 in women.

When the 5-CPTot obtained with the Five-City Project questionnaire was expressed in kilocalories per day, the total level of physical activity was not significantly different to that of healthy subjects.²⁰ However, as discussed above, patients with chronic pain present with a relative excess of body weight, and the 5-CPTot should thus be expressed in kilocalories per day per kilogram to reliably reflect physical activity in overweight subjects. However, 5-CPTot values normalized for body weight are seldom available from the literature. Hence, on the basis of data obtained by Sallis et al.²⁰ in 993 male and 1,111 healthy female subjects, we recalculated the mean 5-CPTot in kilocalories per day per kilogram in 911 men and 1,000 women, after exclusion of their 65- to 74-years-of-age category to age match their subjects with the patients of this study. We obtained mean 5-CPTots of 41 and 36 kcal/d/kg, respectively, in healthy men and women. SDs for these values are unfortunately unavailable from recalculations but may be estimated to be close to 6.5 kcal/d/kg. As compared with the data obtained in the male and female patients of this study (Table 3), these control values are, respectively, 16% and 5% higher; male patients are very significantly less active (Student $t = 4.52$; $p < 0.001$), whereas the reduction in the total level of physical activity in female patients is not significant (Student $t = 1.72$; $p \approx 0.09$).

When analyzing the time spent by patients with chronic pain in this study according to the different intensity categories of physical activity and comparing

with age-matched controls,²⁰ patients spent more time in bed or resting and significantly less time doing light activities. In fact, patients spent approximately the same amount of time resting that they lost in light activities. They also spent approximately the same amount of time doing moderate intensity activities, which, in general, consist of mandatory household tasks such as shopping, sweeping, and mopping the floor. Finally, they demonstrated a major reduction in "hard" and "very hard" categories of physical activity, which generally consist of sports or heavy occupational work.

The total Baecke score was significantly lower in male than female patients, which is usually not the case in healthy subjects.^{16,19,35} Moreover, analysis of the Baecke physical activity subscores (Table 2) revealed that the subscore reflecting occupation was the most affected, especially among males; most male patients had lost their job or had a sedentary occupation. These data obtained with the Baecke questionnaire thus corroborate the data obtained with the Five-City Project questionnaire.

Hence, our data show that the male patients included in this study are clearly less physically active than healthy subjects of the same age. Males with chronic pain behavior seem similar to the healthy elderly who are mostly retired and for whom less intense activities such as light household chores and gardening take a predominant place in daily life.^{15,34}

These observations are in agreement with our hypothesis of a more pronounced effect of chronic pain on the level of physical activity and especially on occupational status in male than female patients. Although job loss is more common in men, the fact that women are kept more active at home by household tasks and child care probably contributes to keeping them at an activity level that may be considered as almost equivalent to that of healthy females in most cases.

Nevertheless, several factors, including patient inclusion criteria and social pressure related to gender, should be taken into account before drawing conclusions that could be extended to patients with chronic pain in general. For instance, men may be referred to the chronic pain unit for help later in the course of their condition (i.e., at a time when their pain already has a greater level of impact on their activity level). They may also be more inclined to emphasize how much they have lost in terms of physical activity and capacity because of social pressures.

Finally, many investigators have studied the relation between fitness and activity level in healthy subjects^{8,36,37} and have found a weak positive significant correlation between CRE indexes and the level of lei-

sure-time physical activity as measured by questionnaire. Other investigators have found no correlation between such variables³⁸ or between $\dot{V}O_2$ max and total weight-bearing physical activity.³⁹ Bouchard et al.^{40,41} have shown that among both main determinants of CRE, training (i.e., physical activity level) and heredity, the latter is the major determinant in sedentary people. Hence, it is not surprising to find a lack of correlation between activity level and fitness in patients who present with a reduced level of physical activity, as discussed above.

CONCLUSIONS

The results of the current study on 55 patients with chronic pain are in agreement with data previously published on the subject: CRE seems to be reduced more by chronic pain in male than female patients. Data on the level of physical activity in patients obtained with two different physical activity questionnaires by the same interviewer showed that the male patients in this study were more sedentary than the female patients. However, several factors, including the selection criteria used in this study and social pressures that may vary with gender, should be taken into account before drawing any conclusions that can be extended to patients with chronic pain in general.

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2.4.7.

MAXIMAL VERSUS SUBMAXIMAL TESTING PROTOCOLS TO EVALUATE FITNESS OF PATIENTS WITH CHRONIC LOW BACK PAIN

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PURPOSE

Maximal testing protocols including direct VO₂max measurements are often implemented in patients with low back pain to evaluate cardiorespiratory endurance (CRE). The validity of such testing procedures may be questioned since such patients may be reluctant to achieve true maximal effort. The aim of this study is to compare maximal oxygen uptake (VO₂max) measured at the end of a maximal testing protocol to VO₂max estimation obtained with a submaximal protocol in patients with chronic low back pain as compared to controls.

METHODS

Eleven patients with chronic low back pain and 10 age- and sex-matched controls achieved in a random order 2 cycle ergometer tests designed to evaluate VO₂max. The first protocol is a maximal multistage gradational cycle ergometer test. During this test, heart rate (HR), oxygen uptake, respiratory gas exchange ratio (RER) and rate of perceived exertion (RPE) are recorded at the end of each stage. All the subjects are asked to perform maximally. The second testing protocol is the Astrand 6-minute submaximal testing protocol which allows VO₂max estimation using the Astrand's nomogram. In patients, pain scores are also obtained before the tests and at the end of them.

RESULTS

In controls, there is no difference in VO₂max according to the testing protocol. In patients, mean VO₂max measured at the end of the maximal test is 20% lower as compared to the value obtained with the Astrand test (paired $t = 3.18$; $p < 0.01$). Mean HR and RER collected at the end of the maximal test are significantly lower ($p = 0.03$ and < 0.01 , respectively) in patients suggesting only submaximal effort. However, mean RPE value scored by the patients at the end of the maximal test is not different from controls. Pain scores obtained from patients at rest before the tests are not significantly different. The increase of pain after the maximal test was very significantly higher (paired $t = 3.32$; $p < 0.01$).

CONCLUSION

Maximal testing protocols may lead to a systematic underestimation of aerobic capacity of patients with pain. They are thus probably not valid to evaluate CRE of such subjects. Moreover, they are often responsible for a significant pain increase which make them generally unsuitable for routine clinical use.

CHAPTER 3 : GENERAL DISCUSSION

As explained in the introduction, we will now address the main issues of this thesis and discuss them, point by point. In this *General Discussion*, our research results will be discussed and compared to those obtained by other investigators. We will thus take the opportunity to throw a global look at the methodology that should be used to assess physical fitness in patients with pain, at the conclusions that should be drawn from studies on fitness and 'physical reconditioning' of patients with chronic pain and, finally, at some more specific topics such as exertion and pain as perceived during exercise by such patients. Broadening the spectrum of the discussion that can be found in our previously published studies seems relevant since other investigators have published more recent results on the topics of our studies.

3.1. DEFINITION OF PHYSICAL FITNESS AND RELATED CONCEPTS IN THE CONTEXT OF CHRONIC PAIN

Patients with chronic pain are generally thought to be less physically active and unfit. Hence, many studies that focused on fitness evaluation and so-called 'physical reconditioning' of such patients can be found in the literature. In most studies, traditional fitness testing procedures that have been validated in healthy subjects only have been implemented in patients with pain with only little discussion on the reliability of such methods in that context. It is also surprising that important conclusions that significantly influenced treatment strategies have been drawn from such studies. In many studies, concepts such as physical fitness and performance in physical tests are confounded. Hence, before addressing

the validity and reliability of fitness testing in the context of pain, physical fitness and other related terms must obviously be defined.

Physical fitness is generally defined as a set of attributes that people have or achieve that relates to the ability to perform physical activity ²⁷. It is a multi-factorial construct that includes several components: cardiorespiratory endurance (CRE), muscular strength and endurance, flexibility (range of motion, mobility) and body composition, although CRE is generally considered as the most fundamental attribute ⁸⁹. In some of the numerous definitions of physical fitness, coordination (motor control) is also included among the main components of the fitness construct as all components are movement-related traits.

The fitness concept has long been used in the context of performance in sports and recreational activities. It is only recently that the relationship between fitness and functional capacity in daily and/or household activities has been studied. Fit and active healthy individuals aged 40 and older present with less functional limitations ⁶². Physical fitness encompasses not only cardiac and respiratory systems performance but also mobility, strength and coordination, which are attributes of the locomotor system. Physical fitness or capacity should thus be regarded as the major determinant of physical performance and function ¹⁷⁹. Later in this manuscript, physical fitness and physical capacity will be used indifferently as we will consider both terms as synonyms.

A good level of CRE provides individuals with an increased cardiovascular and respiratory reserve during submaximal-intensity physical activities. Hence, we consider that fit individuals also present with what could be defined as an increased 'locomotor reserve'. Such an increased 'locomotor

reserve' practically implies that locomotor system would relatively be less stressed during normal daily life activities such as household, occupational and recreational activities in fitter individuals. Such a mechanism could explain why physical fitness could have a protective effect against back injuries.

Health-related physical fitness is described as components of physical fitness that are associated with some aspects of good health and disease prevention^{89, 101}. Noteworthy, in the last edition of the McArdle, Katch and Katch textbook on exercise physiology, the authors define the four most common components of health-related fitness as cardiovascular (aerobic) fitness, body composition, abdominal muscular strength and endurance and lower back and hamstring flexibility¹⁰¹. Such a recent definition of health-related fitness fits particularly well in the context of back pain prevention.

As will be discussed further in this manuscript, many factors may limit physical performance. Physical fitness is probably one of the most important factors and any lack of fitness should be considered as an actual physical impairment (deficiency or deficit) according to the World Health Organization definitions for 'physical impairment', 'disability' and 'handicap'.

In summary, physical fitness is a set of physical attributes that relate to the ability to perform physical activity. It is a multi-factorial construct that includes several components, which are:

- ***cardiorespiratory endurance (CRE),***
- ***muscular strength and endurance,***
- ***flexibility (range of motion, mobility),***

- *motor control,*
- *body composition.*

Cardiorespiratory (CRE) endurance is the most fundamental component of fitness. Physical fitness is a major determinant of physical performance or function as fit individuals present with better cardiovascular, respiratory and locomotor reserve.

3.2. 'MAXIMAL' PHYSICAL FITNESS TESTS IN PATIENTS WITH PAIN

Most physical fitness testing procedures require maximal effort from the examinee. By definition, in strength and flexibility testing and in most cardiovascular capacity testing protocols the subjects are asked to perform a standardized task maximally. Hence, motivation and instructions⁹⁵ given to the subject play key roles in how 'maximal' the task is performed.

We recently showed that, when aerobic fitness of patients with chronic back pain is evaluated by both a maximal and a submaximal testing protocol, the maximal protocol led to a very significant underestimation of fitness¹¹⁹. Wittink et al. demonstrated that patients with chronic pain could reach higher aerobic power when tested on a treadmill as compared with a cycle ergometer¹⁸⁴. However, even in the treadmill test that yielded the highest oxygen uptake and HR values, the effort remained significantly submaximal as suggested by the much higher predicted maximal oxygen and HRs. Wittink et al. showed that more than half of chronic low back pain patients prematurely stop a maximal treadmill test because of a significant increase of pain^{183, 184, 186}. Battie et al. reported that 16% failed to reach predetermined target HR (80% of maximal HR) during a submaximal treadmill test¹¹. Schmidt observed that patients with chronic pain performed only submaximally on a treadmill test and that the introduction of a high frame of references (informing the subjects about the elapsed time and communicating high expectations about the performance that is expected from the subject) produced a tendency toward somewhat better physical performance¹⁴⁶. Clearly, many arguments can be found in the

literature indicating that patients with pain perform only submaximally in so-called 'maximal' physical tests.

Khalil et al. stressed that maximal function testing was not acceptable in patients with back pain in relation with the risk of re-injury and exacerbation of the painful condition ⁷⁵. Consequently they introduced an original psychophysical measure of strength better suitable for patients with back pain (Acceptable Maximal Effort: AME). Unfortunately they neither discussed nor evaluated the relations between such a psychophysical variable and 'maximal voluntary strength' measures obtained through more traditional protocols in patients with pain.

3.2.1. Why not recommend traditional testing requiring maximal effort to assess physical fitness in patients with pain?

Harding et al. suggested that some physical testing procedures, e.g., aerobic testing which is often achieved through maximal testing protocols, could be unacceptable for the more disabled patients who tend to avoid feared activities and movements ⁵⁶. Pain or simply fear of pain, movement or re-injury ^{83, 107, 171} may inhibit the subject with the consequence that their true maximal strength, flexibility or cardio-respiratory endurance may be systematically underestimated.

Newton and Waddell underlined that actual performance level may be affected by pain, by unconscious psychological factors or by conscious factors ¹¹⁷. While true malingering is rather exceptional, medico-legal issues involved in work compensation and psychological factors ⁶⁸ may explain the poor performance of patients with pain in physical tests. Harding et al. underlined that a score of zero obtained by some patients in a simple sit-up test should be considered as an indicator of the patient's

fears rather than his performance on that test ⁵⁶. They also recalled that patients with pain frequently approach physical tests with strong pessimistic beliefs concerning the physical activities they are capable of performing, resulting from previous unpleasant experience or from medical or paramedical advices. After studying the relationship between lumbar dynamometry variables and the Waddell score reflecting illness behavior¹⁷⁷, Hirsch et al. concluded that poor performance on a physical test might reflect illness behavior more than true loss of physical capacity ⁶⁰.

Lethem et al. ⁸⁴ introduced the fear-avoidance behavior model in the early eighties. It refers to avoidance of movements or activities generally based on fear. Later Vlaeyen et al. further developed it ^{2, 6, 23, 30, 71, 171, 172}. Such a model describes patients with pain as fearing and avoiding physical activities in general and activities requiring maximal exertion in particular. Vlaeyen et al. recalled that there is sufficient evidence that pain-related fear is associated with escape or avoidance of physical activities resulting in poor behavioral performance ¹⁷². These authors also stressed that such a phenomenon may account for poor results in physical tests conducted in a laboratory. For instance, they showed that performance of a simple maximal physical test (holding up a 5.5 kg bag as long as possible in a standing position) was reduced in patients with chronic low back pain who scored high on a Dutch version of the Tampa scale for 'kinisophobia' ¹⁷¹. Crombez et al. reported a strong inverse correlation between several pain-related fear measures and physical performance which led the authors to conclude that pain-related fear was more disabling than pain itself ³⁰. Hupli et al. showed that variability in test-retests procedures which reflects submaximal effort was positively correlated with the severity of the back problem as assessed by the Oswestry disability index ⁶⁵.

Kori et al. have underlined that fear of movement may be irrational and have termed this physical activity avoidance behavior as a 'kinisiphobia' ⁷⁹. Not only may such a fear avoidance behavior explain poorer performance at physical tests but it may also play a major role in the development and perpetuation of the so-called deconditioning syndrome ¹⁷².

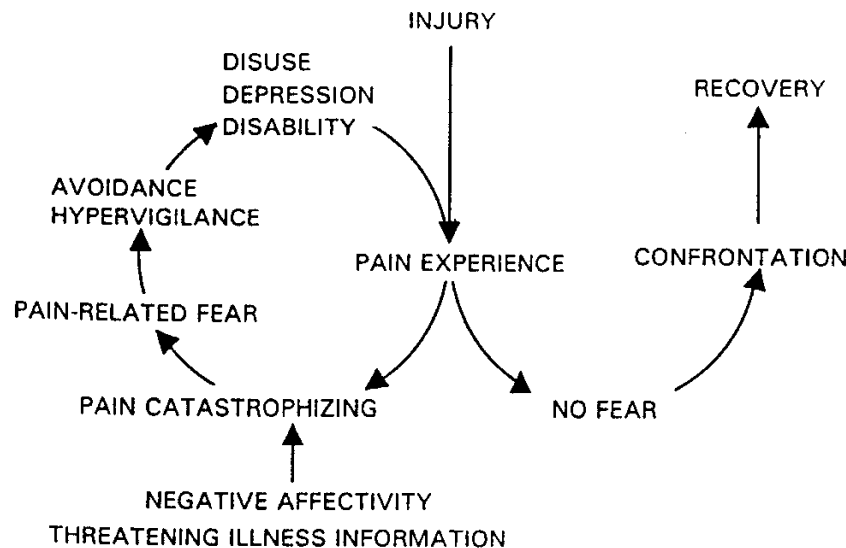


FIGURE 4: A fear-avoidance model for chronic pain after Vlaeyen and Linton (2000) ¹⁷².

After a first pain experience, different attitudes may develop according to the way pain is interpreted. If threatening information has been given to the subject about his condition, pain-related fear may evolve and the patient may become 'pain-catastrophizer'. Such a mechanism may successively lead to activity avoidance behaviors, hypervigilance to bodily sensations, depression, disability and disuse. Finally, a vicious cycle will develop ultimately leading to pain perpetuation, physical activity avoidance and disuse.

Other factors such as negative affectivity, depression, wrong beliefs about the origin of pain, catastrophizing, anxiety, hypervigilance and anxiety may also play key roles in the development of a deconditioning syndrome

following a fear-avoidance model as recently described by Vlaeyen and Linton¹⁷² (Figure 4).

3.2.2. Non physiological determinants of physical performance

Watson reviewed the non-physiological determinants of physical performance in musculoskeletal pain¹⁷⁹. This author recalled that, when physical capacity is determined by physiological factors, physical performance at most tests is determined by physical and psychological factors. Among non-physiological determinants of physical performance Watson cited fear avoidance beliefs as well as self-efficacy, pain self-efficacy, current pain, outcome expectancy and several other factors (Figure 5). Watson did not specifically make a difference between maximal and submaximal testing procedures. In our opinion, the term 'physical performance' specifically refers to results obtained through maximal testing and should thus not be applied to measurements obtained with submaximal physical tests.

Performing well at maximal physical tests is clearly not only a matter of muscle size or cardiovascular capacity. Performances recorded during maximal physical tests are determined by numerous physical and psychological factors. In patients with chronic pain, behavioral factors may considerably limit the intensity of effort, and the result is seldom actually maximal. Rudy and Stacey stated that strength tests and many other physical tests should better be conceptualized in order to provide behavioral rather than physical measures¹⁴¹.

Physical Performance in Chronic Pain

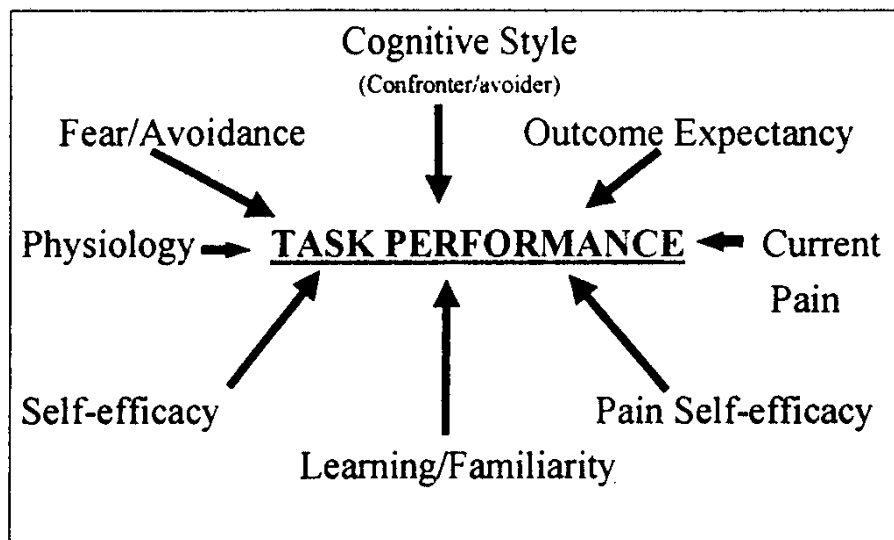


FIGURE 5 : Non-physiological determinants of physical performance in patients with pain after Watson (1999) ¹⁷⁹

Hence, assessing how maximal an effort was during a maximal physical capacity test could provide the evaluator with valuable information on the validity of the test and, indirectly, on the presence of fear avoidance behavior. This could lead the evaluator to carry out more specific behavioral assessment tools such as the Tampa Scale for Kinesophobia ⁷⁹, the Fear Avoidance Beliefs Questionnaire ¹⁷⁸, and/or the Pain Anxiety Symptoms Scale ¹⁰⁴. Unfortunately, scaling the relative intensity of the effort that a subject supposedly performed maximally is actually impossible in the context of strength and flexibility evaluations in patients with pain. Vlaeyen and Linton suggested that detecting submaximal muscle contraction during voluntary contraction using the superimposed percutaneous twitch technique as described by Rutherford et al. ¹⁴² should be possible ¹⁷². Even if such a hypothesis were confirmed, achieving maximal muscle contraction through electrical stimulation in patients with pain seems unreasonable. As underlined by Rudy and Stacey, attempting to

measure pain patients' true maximal physical capacity seems not only unethical and contraindicated but also unrealistic ¹⁴¹.

In summary, performances obtained through maximal physical tests are determined by physical, but also psychological factors. Maximal physical tests provide behavioral rather than physical measures. In particular for patients with pain, pain itself and psychological factors such as fear avoidance behavior may considerably limit the intensity of effort during maximal physical tests.

3.3. CARDIORESPIRATORY ENDURANCE EVALUATION IN PATIENTS WITH CHRONIC PAIN

3.3.1. Maximal CRE tests as applied to patients with pain

Cardiorespiratory endurance (CRE) is generally considered to be the most fundamental component of fitness. However, only relatively few studies have focused on its evaluation in patients with pain in contrast to the numerous studies that have focused on trunk strength evaluation. Most studies that included CRE evaluation simply implemented maximal testing protocols designed to measure or estimate maximal oxygen uptake (VO_2max) in healthy subjects. Graded treadmill or cycle ergometer exercise protocols traditionally used in cardiology or sport physiology were thus often implemented in patients with chronic pain, although the acceptability and reliability of such methods may be questioned in the context of pain patients physical function evaluation⁵⁶.

Maximal oxygen uptake (VO_2max) is generally considered as the best CRE index. In healthy subjects, VO_2max is generally measured at the end of graded exercise protocol in which the examinee should have reached maximal physical exertion.

We conducted a study designed to evaluate whether patients with chronic low back pain could reach maximal aerobic power during a traditional VO_2max test¹¹⁹. Maximal oxygen uptake of 11 patients with chronic low back pain and 10 age- and sex-matched healthy controls was evaluated with two different methods. The first method was a traditional maximal cycle ergometer protocol at the end of which VO_2 was measured. The second method was the well-known Astrand 6-minute submaximal cycle ergometer protocol that yields a reliable VO_2max estimation using the Astrand nomogram⁹ and the age-correction factor⁷. When both testing methods

yielded non significantly different VO_2max values in controls confirming the reliability of the Astrand method in healthy subjects, mean VO_2max obtained at the end of the maximal test was in average 20% lower than the values obtained with the Astrand procedure. Significantly lower respiratory exchange ratios and HRs measured in patients at the end of the maximal test strongly suggested that the so-called 'maximal' test was in fact physiologically submaximal in most subjects with pain. None of the criteria indicating that maximal maximal aerobic power was reached¹⁰¹ were met (a leveling off or peaking of VO_2 measures, a respiratory exchange ratio superior to 1.15 and, an attainment of the age-predicted maximum HR).

Wittink et al.¹⁸⁴ recently conducted a study aimed at determining in patients with chronic low back pain which test yielded the highest peak VO_2 , among several maximal aerobic fitness testing procedures. They showed that the highest VO_2 were achieved with a maximal treadmill test (modified Bruce treadmill protocol) as compared with a cycle ergometer test or a test performed on an upper extremity ergometer. However, even on the treadmill peak VO_2 was significantly lower (31%) than the VO_2max that could be predicted by extrapolation on the basis of the VO_2 versus HR regression. Even on the treadmill, where effort was the most intense, back pain subjects only reached an average of 81,4% of the maximal theoretical HR; the criteria of a maximal effort were not met.

In an even more recent brief report, Wittink et al.¹⁸⁵ studied the association of pain with aerobic fitness in patients with chronic low back pain. In that study, peak VO_2 measures at the end of a maximal treadmill test were, on average, 36% and 33% lower than the predicted VO_2max in males and females, respectively. 'Maximal' HR reached by subjects of both

genders was on average 145 beats per minute (bpm), which is largely submaximal since, at a mean age of 40 years, they should theoretically be able to reach a HR of 180 bpm. The criteria indicating maximal effort were not achieved in this study.

In general, patients with pain perform submaximally in CRE 'maximal' testing procedures as they do in strength testing. However, a closer look at our data and those of Wittink et al. shows that the level of intensity reached by each subject taken individually is highly variable. Some patients with pain are indeed able to reach an intensity level that is close to the maximum if not the actual maximum.

Hence, if 'maximal' strength measures obtained in patients with pain should be considered as psychophysical and/or behavioral variables rather than as physical ones, so do 'maximal' physiological measures obtained at the end of so-called 'maximal' CRE tests.

3.3.2. Evaluation of CRE through submaximal testing procedures in patients with pain

Contrary to strength testing, CRE can be reliably evaluated with sufficient accuracy through testing protocols that only require sub-maximal exertion (sub-maximal testing protocols)^{7-9, 101, 103}. HR varies linearly with oxygen uptake; thus, maximal testing is not mandatory to evaluate VO_2max ¹⁰³. For instance, VO_2max can be predicted by extrapolating the VO_2 versus HR measurements made at the end of submaximal stages, during which a steady state is achieved, to the value of VO_2 at the maximal theoretical HR¹⁰³. VO_2max can also be estimated without any oxygen uptake measurements from the HR and the corresponding workload recorded at the end of a 6-minute single stage cycle ergometer test using the Astrands' nomogram⁹.

Submaximal physical working capacity indices such as the PWC_{170} are also often used as valid and reliable CRE indices. They are obtained by calculation from the linear HR versus workload relationship obtained by monitoring HR during a multistage submaximal cycle ergometer test^{8, 67, 182}. The PWC_{170} is expressed in watts and represents the workload that a subject is able to sustain on a cycle ergometer at a constant HR of 170 bpm. Such an index has been used to evaluate CRE of patients with fibromyalgia^{20, 102}. It may also be normalized for body weight (PWC_{170}/kg) and expressed in watts/kg. The difficulty encountered with the PWC_{170} index is that it was originally designed for CRE assessment in relatively young subjects. Obviously, an exercise-intensity corresponding to a HR of 170 bpm will only be submaximal and thus sustainable in young individuals. On the other hand, a PWC_{170} obtained in a 60 year old subject makes no physiological sense since the maximal HR of a subject of that age may be estimated to be close to 160 bpm (maximal HR = $220 - \text{age}$ ⁸). Hence, other similar physical working capacity indices calculated at lower HR such as the PWC_{160} , PWC_{150} , and PWC_{130} have been used in studies involving older pain patients^{24, 105}. A major limitation of such CRE assessment methods is that only subjects included in a relatively small age range may be reliably evaluated and classified with such indices. Obviously, using a PWC_{170} to evaluate and compare both a 20- to 50-year-old subject would be equivalent to compare exercise intensities corresponding to 85% and 100% of maximal HR for the first and second subject, respectively. To avoid this pitfall, we were the first to use a physical working capacity index calculated for a HR of 65% of the HR-reserve according to the Karvonen⁶⁹ formula¹²³. We introduced the $PWC_{65\%}/kg$ as a CRE index and used it to evaluate physical fitness of various groups of patients with chronic

pain^{118, 122-124}. The $PWC_{65\%}/kg$ allows the working capacity to be expressed at the same relative effort intensity independently of age. It may thus be used in studies including subjects of a wide age-range. We chose 65% of the HR-reserve to calculate the $PWC_{65\%}/kg$ since it corresponds to an exercise intensity generally considered as a good intensity target during reconditioning programs^{1, 129}.

Gore et al.⁵³ proposed later another equivalent index (the $PWC_{75\%}/kg$) to estimate CRE in epidemiological and population-based studies. They demonstrated that, contrary to PWC_{170}/kg and other similar indices, the $PWC_{75\%}/kg$ had good face validity as a method of evaluating aerobic fitness in both men and women aged 18 to 78 years since it declines about 9% per decade of age as does VO_{2max} . Gore et al also showed that the $PWC_{75\%}/kg$ was able to distinguish active from sedentary subjects.

We studied the reliability of the $PWC_{65\%}/kg$ in healthy subjects and in patients with chronic pain¹²³. We showed that a step-test and a cycle ergometer gave equivalent $PWC_{65\%}/kg$ in healthy subjects and that the $PWC_{65\%}/kg$ was reliable in healthy subjects and in patients with chronic pain¹²³. We also pointed out that CRE indices such as the $PWC_{65\%}/kg$ will probably be invalid in patients taking medications that affect the HR versus power relationship. We reported a significantly lower $PWC_{65\%}/kg$ in patients under psychotropic agents. Obviously, such an observation in a cross-sectional protocol needs to be confirmed by a longitudinal study design. It is likely that any drug affecting HR during exercise will alter the value of the $PWC_{65\%}/kg$. In patients with chronic pain, tricyclic psychotropes (anticholinergic positive chronotrope effect) and β -antagonists (negative chronotrope effect) are the most commonly

prescribed medications susceptible to invalidate such physical working capacity indices.

Theoretically, criterion validation of the PWC_{65%}/kg as well as other equivalent indices such as the PWC_{75%}/kg, still requires comparison to directly measured VO₂max. However, the issue will be difficult if not impossible to address in patients with pain since the 'gold standard' parameter reflecting CRE is VO₂max measured at the end of a maximal test, by definition. We have shown that submaximal CRE testing was reliable in patients with chronic pain¹²³. Moreover, 'organic' origin of symptoms in patients with chronic pain is generally limited to the neuro-locomotor system. Hence, there is no obvious reason why such CRE testing procedures should not be valid in the context of physical capacity evaluation of patients with chronic pain.

In summary, cardiorespiratory endurance (CRE) is the most fundamental fitness component. Maximal oxygen uptake (VO₂max) is generally considered as the best CRE index. In healthy subjects, it is generally obtained directly by measuring VO₂ at the end of maximal gradational testing protocols. Such testing methods have not been validated in patients with pain. Abundant evidence can be found in the literature indicating that most patients with pain perform only submaximally in traditional VO₂max tests. We recently conducted a study that demonstrated such submaximal performance.

VO₂max can also be estimated through submaximal tests that should be preferred in the context of pain. For instance, VO₂max can be reliably estimated using the Astrand submaximal cycle ergometer test.

Physical working capacity (PWC) indices can also be used as reliable CRE indices. They are obtainable through submaximal cycle ergometer tests. We developed the $PWC_{65\%}/kg$, which allows valid and reliable assessment of CRE, independently of age. The $PWC_{65\%}/kg$ is particularly suitable for routine clinical evaluation of patients with chronic pain or other chronically ill subjects.

3.4. WHICH TEST IS THE BEST TO EVALUATE THE FITNESS OF PATIENTS WITH CHRONIC PAIN?

3.4.1. Multidimensional versus unidimensional physical tests in the context of pain

As discussed above, maximal physical tests are influenced by numerous physical and psychological factors. They should thus be considered as multidimensional evaluations of physical performance. Nevertheless, a lack of physical fitness may be defined simply as a physical deficit according to the World Health Organization definitions for deficiencies, impairments and handicaps. Unidimensional tools are thus needed that focus more specifically on the physical characteristics of pain patients. Since CRE and body composition are the only components of fitness that do not require maximal effort from the examinee, it may be hypothesized that they are the only ones to be available for valid unidimensional fitness evaluation in patients with pain.

3.4.2. Acceptability of physical tests as applied to patients with pain

In defining the best physical capacity testing procedure to be used in patients with pain, the issue of acceptability should also be considered⁵⁶. Since fitness testing is relevant as part of the comprehensive evaluation of patients with chronic pain, it should also be useful in fitness gains monitoring during physical reconditioning programs. Hence, testing procedures that are accompanied by systematic significant pain enhancement should obviously be avoided. We reported that submaximal bicycle CRE tests were well tolerated by patients with pain¹²⁴. Moreover, we showed that the submaximal cycle ergometer testing procedure we used was associated with a significant pain decrease in 5% of the subjects. On

the other hand, Wittink et al.¹⁸⁵ reported that the mean pain score increased very significantly after a maximal treadmill test (the modified Bruce protocol). Furthermore, the pain scored after the test was higher than after a traditional maximal cycle ergometer test or a maximal upper limb ergometry test¹⁸⁴. Moreover, pain was the most common reason for the patients to terminate the treadmill test.

Robert et al. reported that during a physical reconditioning program where chronic pain patients could freely choose their preferred aerobic exercise among treadmill walking or running, speed walking, upper limb ergometry, stair climbing and stationary bicycle, the majority of subjects chose stationary bicycle¹³⁷.

Harding et al. reported that acceptability of several tests of a battery of simple physical tests was good except for sit-ups⁵⁶.

Several hypotheses can be proposed to explain why the majority of patients with back pain and/or sciatica prefer cycle ergometry. During cycling, the subject is sitting on the saddle, causing less strain for the lower limbs than walking or running. Patients may also feel safer on a bicycle as compared to a treadmill, especially at higher exercise intensities. Stationary cycling may also be more comfortable for the back as no impacts are transmitted from the ground. In patients with lumbar facet joint arthritis and/or spinal stenosis due to hypertrophic degenerative changes in the facet joints, cycling may even alleviate pain since bending forward decreases pressure in the facet joints and widens the spinal canal.

In summary, any measure obtained from maximal physical testing procedures should be considered to be multidimensional. Although psychophysical variables may be useful, the need for valid and reliable

unidimensional measures of physical fitness in patients with chronic pain is obvious. In that context, such measures of physical fitness should preferably be obtained by a simple submaximal CRE test combined with body composition assessment.

Acceptability for the patient should also be considered because regular CRE assessment could be usefully conducted to monitor fitness gains during a comprehensive rehabilitation program. In that context, we showed that submaximal cycle ergometry seems well tolerated by most patients.

3.5. ARE PATIENTS WITH CHRONIC PAIN UNFIT AND LESS ACTIVE?

As previously discussed, maximal physical testing procedures systematically underestimate actual physical capacity in most patients with chronic pain. Hence, only studies using submaximal CRE testing procedures will be considered in this section. Along with 3 of our studies¹²²⁻¹²⁴, we considered five other cross-sectional studies that focused mainly on chronic and/or recurrent back pain patients presenting useful data^{11, 22, 164, 183, 184}. Although Wittink et al.^{183, 184} used a maximal treadmill test to evaluate aerobic fitness, they also presented predicted VO_2max values that are considered here since they are equivalent to VO_2max estimation through submaximal testing. It must also be emphasized that among those 8 cross-sectional studies 2 came from the same group and 3 others from another group that each time used the same methodology. Many studies also reported on fitness of patients with fibromyalgia that will be discussed further in this section. Several studies were excluded because the data presentation did not allow clear and relevant analysis. For instance, although it is well known that CRE is age and gender dependent^{8, 101}, several studies failed to present results separately for males and females and/or others did not provide sufficient information about ages of patients.

Among the eight cross-sectional studies that were considered in this review, only five included age- and sex-matched controls that were evaluated with the same submaximal testing procedure^{11, 22, 123, 124, 164}. The other three studies compared the results obtained in patients to normative CRE data available in the literature^{122, 183, 184}. Such comparisons should be looked at more cautiously since testing procedures and protocols may vary considerably, although in one of our study¹²², the testing procedure was

the same. For example, van der Velde and Mierau evaluated CRE of healthy controls and found it was significantly reduced compared to normative data obtained by other authors in healthy subjects using the same test 10 years earlier ¹⁶⁴.

3.5.1. Lower CRE, only in male patients with severe chronic pain

Among the prospective cross-sectional studies which included a control group, all but one ¹¹ reported significantly lower CRE in patients. However, chronic pain may affect patients of both genders differently. We showed that CRE as evaluated by the $PWC_{65\%}/kg$ was significantly reduced in males and still normal in females. It should be underlined that we obtained similar results in three different studies ¹²²⁻¹²⁴ including three different groups of patients with chronic pain. After retrospectively analyzing the patients' charts, we hypothesized that socio-cultural factors could account for such surprising findings. We indeed noted that most male patients had physically more demanding occupations before the pain started and subsequently lost their jobs. Among females, of the one third who were employed before the onset of pain, half were still employed at the moment of the study because their job was less demanding physically. Moreover, female patients were generally more active once at home as they were still engaged in childcare and various household duties. On the contrary, most male patients, after losing their job, presented with a very low level of daily physical activities (Figure 6). We conducted a prospective study specifically aimed at evaluating this hypothesis ¹²². Therefore, we measured the $PWC_{65\%}/kg$ and evaluated physical activity level in 55 consecutive patients with chronic pain and showed that both fitness and activity level were more affected in males, which corroborates our

hypothesis. Interestingly, other authors reported similar results suggesting that, on both sides of the Atlantic Ocean, chronic pain may affect male patients more in terms of fitness and activity level ^{22, 183}.



Figure 6 : Male and female patients with chronic pain as drawn by
Pierre Kroll

3.5.2. Studies reporting normal level of CRE in patients with low-back pain

Several studies reported normal ^{11, 66} or nearly normal CRE ¹⁸³ in chronic low back pain patients.

Verbunt et al. who recently reviewed this subject report that, as previously suggested by us, work status was an important issue in interpreting aerobic capacity of patients with chronic low back pain ¹⁶⁸. They also stressed that information on work status was unfortunately not available in all studies.

The studies of Battie et al. ¹¹ and Hurri et al. ⁶⁶ which reported normal CRE in patients with back pain included still-working subjects only. In the study of Wittink et al. ¹⁸³ which reported only a small reduction in CRE in male

patients only, about half of the patients still had an occupation, at least part time.

Hence, the contradictory results about fitness levels of patients with chronic pain reported in the literature are probably explained by the wide range in severity of the cases studied. It seems indeed obvious that the activity and physical fitness levels of the still working aircraft manufacturing employees studied by Battie et al. should be different than that of the third referrals chronic pain patients that we evaluated, who all lost their job years before being evaluated.

3.5.3. Fitness of patients with fibromyalgia

Fitness has also been studied in the context of fibromyalgia. Patients with fibromyalgia are generally thought to be unfit. However, the only studies that reported lower aerobic fitness levels used traditional maximal testing protocols^{14, 125, 162, 163}. We conducted a prospective cross-sectional study comparing the CRE of 30 female patients with fibromyalgia to 67 age-matched female controls and found normal aerobic fitness in the patients¹¹⁸. A type II error could not be excluded due to a relatively small number of patients, as indicated by the p value of 0.08. However, even if statistically significant, the very small decrease in fitness level observed in the patients with fibromyalgia (9% reduction of the physical fitness index with a z score value of -0.38 in patients as compared to controls) would have no clinical relevance. We pointed-out that another study which used a submaximal testing procedure to estimate CRE also reported normal fitness level in patients with fibromyalgia¹⁰⁸. Hence, as it generally is in patients with chronic pain in general, fitness of most female patients with fibromyalgia is still probably within the normal range.

3.5.4. Physical activity level of patients with chronic pain

While many studies have been conducted to evaluate physical fitness of patients with pain, only a few have focused on assessing the physical activity (PA) level in such patients. We evaluated PA level of patients with severe chronic pain with two different questionnaires ¹²². We reported that the gender-difference in PA level that normally characterizes healthy controls was not present in patients with severe chronic pain, suggesting that male patients with chronic pain are less active than females.

On the contrary, Verbunt et al. ¹⁶⁹ and Protas et al. ¹³⁰ found PA level of chronic pain patients comparable to healthy subjects. As underlined by Verbunt et al., these contradictory results are probably explainable by the fact that the severity of the cases of the patients included in those studies differed greatly. In our study, only 20% of the male and 34% of the female patients, were still occupied. However, in the study of Verbunt et al. which evaluated PA level by triaxial accelerometry and doubly labeled water methods, 77% of the patients still had an occupation.

Hence, in assessing PA level of patients with chronic pain, work status is obviously an important factor that must be taken into account ¹⁶⁸.

3.5.5. Assessment of PA level in patients with chronic pain and/or other chronic illnesses

In a different clinical context, we conducted a longitudinal study aimed at following-up the PA level of 32 renal transplant recipients before and after transplantation by two well-known questionnaires ¹²⁰. In that study, we discussed the validity of self-report methods to assess PA levels of chronically ill, and pointed-out that the very low values of PA level obtained with questionnaires in such patients should be considered with caution.

Verbunt et al. recalled that chronic pain patients' perception of their activities might be biased by other pain related factors, which may affect the validity of their self-reports ¹⁶⁸.

Measures of PA by triaxial accelerometry have been shown to correlate well with results obtained by doubly labeled water in patients with chronic pain ¹⁶⁹. Hence, such a simple, relatively cheap, non-invasive and more direct method should probably be preferred in the future to assess PA of patients with chronic pain

In summary, only a few studies have focused on evaluating the aerobic fitness of patients with pain using submaximal testing methods. Most studies reported lower fitness levels in patients with chronic pain and several studies showed that the fitness level of the male patients was more affected than females, probably as a result of socio-cultural factors. This phenomenon probably only characterizes the most severe cases where job loss is almost systematic. The only studies that reported normal fitness levels in chronic low back pain patients included still working subjects. Hence, work status is an important factor to take into account when interpreting the physical fitness level of patients with pain.

Studies on the physical activity level of patients with chronic pain are even less common. Their findings are in agreement with data on fitness levels reported in similar subjects. Although male unemployed patients with chronic pain are less fit and less active on average, the physical characteristics of each patient taken individually should always be considered during comprehensive evaluation procedures, since fitness and activity levels of patients with pain are generally highly variable.

3.6. IS PHYSICAL RECONDITIONING HELPFUL IN PATIENTS WITH CHRONIC PAIN?

3.6.1. Exercise programs and chronic pain

Studies reporting results of therapeutic programs based on exercise for patients with chronic pain are numerous. Such therapeutic interventions probably became very popular as a result of the very enthusiastic data reported by the Mayer group after so-called 'functional restoration', especially in terms of return to work rate⁹⁷⁻⁹⁹.

In 1991, Koes et al.⁷⁷ conducted a blinded review on exercises and back pain aimed at evaluating the quality of such studies. As emphasized by Koes et al., the quality is generally poor since most of these studies have significant shortcomings such as: lack of description of drop outs, small sample sizes, use of concomitant interventions, absence of placebo control group, lack of blinding of patients and of intention to treat analysis. Hence, although encouraging results have been reported in terms of physical capacity gains, functional improvements, pain alleviation, return to work rate, quality of life, actual efficacy of exercise in patients with chronic pain is still debated.

Van Tulder et al.¹⁶⁵ reviewed the studies on conservative treatments of acute and chronic low back pain. Among 23 randomized clinical trials (RCTs) on the subject, they selected and scored 16 studies that focused on the efficacy of exercise in low back pain according to 17 methodological quality criteria. Among the 16 studies, 8 reported positive results and 8 reported negative ones. However, positive results were more often reported by better quality studies. For instance, the three high quality RCTs reported positive results. Van Tulder et al. concluded that there is strong evidence that exercise therapy is effective for chronic low back pain patients.

3.6.2. Exercise and fibromyalgia

We recently reviewed the effects of exercise in patients with fibromyalgia¹²¹. We recalled that most authors agree that exercise should form part of the comprehensive therapeutic programs of most patients with fibromyalgia and that a clear, specific, positive effect on the chief symptom of fibromyalgia, namely, pain, has not yet been demonstrated. However, we reported that patients with fibromyalgia seem to improve with exercise although such patients' physical fitness is still probably within the normal range as previously discussed.

After reviewing the efficacy of exercise as a treatment in fibromyalgia, Mior concluded that there is moderate evidence that exercise will be beneficial in the short to intermediate term¹⁰⁹.

3.6.3. How do exercise programs benefit patients with chronic pain?

Exercise programs provide chronic pain patients with better physical function and improved quality of life through several ways. Improvement of physical capacity could straightforwardly be a determinant mechanism in very physically unfit and sedentary patients. Other mechanisms may also play important roles in less unfit individuals.

Kohles et al.⁷⁸ of the Mayer group studied the addition of an educational pre-program phase to traditional physical reconditioning emphasizing trunk strength and flexibility exercises. That preliminary phase mainly constituted of education about the principles of functional restoration. They reported better overall improvements when exercises were combined with education and hypothesized that education produces an earlier decrease of inhibitory factors, both neuromuscular and psychological, that otherwise negatively impact rehabilitation efforts. They argued that

disinhibition of limiting factors such as fear of re-injury could in itself lead to better physical performance independently from any true gain in physical capacity. Such a hypothesis was supported by later findings of Cook et al.²⁹ who reported in patients with chronic low back pain muscle strength increase after training greater than physiology could explain.

Rainville et al.¹³¹ showed that exercising without significant pain enhancement could alter the control that pain had over the individual with chronic pain in terms of participation in physical activities.

Vlaeyen et al.¹⁷⁰ hypothesized that, in analogy with the treatment of phobias, isolated graded exposure to back-stressing movements may be successful in treating back pain patients presenting with substantial fear of movement and re-injury. They conducted a replicated cross-over single case design study comparing the effects on graded exposures to highly feared movements and graded physical training with less feared exercises on pain-related fear, pain cognition and pain disability. They observed that graded exposure only led to a major and abrupt decrease in pain-related fear. Statistical analysis revealed that significant changes occurred only when graded exposure was introduced. As Vlaeyen et al. argued, an abrupt effect of such a magnitude is suggestive of cognitive changes, such as a reduction in catastrophizing which is thought to play a major role in the initiation and perpetuation of chronic pain syndromes as previously discussed. Surprisingly, graded activity alone did not lead to any decrease of pain-related fear. However, Vlaeyen et al. recalled that exercises that elicited substantial fear were excluded from the graded activity program in order to avoid contamination between both treatments. Hence, activities selected for the graded activity regimen were probably quite different from Mayer's functional restoration programs or any exercise program

where patients are progressively asked to perform varied strengthening exercises including lifting tasks, which they usually fear.

Just as physical function and performance are not only a matter of muscle size, improvement after exercise-based interventions in patients with chronic pain is explainable by psychological mechanisms as well as by physical capacity gains. Vlaeyen et al. have shown how strong and rapid the cognitive effect of proper education could be. It must be recalled that such an effect is probably observable after most of the exercise programs. Indeed a rationale including at least minimal explanations on the reasons why exercising is generally provided to obtain adherence to the treatment. Findings of Vlaeyen et al.¹⁷⁰ enlighten that such a rationale should emphasize explanations on the origin of pain as conceptualized in the fear-avoidance model¹⁷² and not only on improving physical capacity. Moreover, comprehensive psychological and physical evaluations with specific valid and reliable tools should help tailor rehabilitation programs to the needs of each patient with chronic pain.

In summary, well-conducted exercise programs, combined with education, improve the physical functioning and overall quality of life of most patients with chronic pain. Such improvement is obtained through several mechanisms. In very unfit and inactive patients, physical reconditioning obviously leads to better physical functioning. If proper education is provided as part of the program, a strong cognitive change may take place. After successful confrontation to previously feared physical activities, the patient becomes progressively more active in every day life, which ultimately reverses the vicious fear-avoidance cycle. Better physical capacity and function, and a major change of

attitude towards physical activities in general are the most significant benefits of exercise programs.

3.7. HOW DO PHYSICAL ACTIVITY AND PAIN RELATE IN PATIENTS WITH CHRONIC PAIN?

It has often been hypothesized that if physical exertion is systematically accompanied by pain enhancement, such activity-related pain, through classical conditioning, could lead to activity avoidance. Such a hypothesis was already challenged in 1981 by Fordyce et al.⁴¹ who showed that pain behaviors were not inextricably related to the amount of exercise performed in patients with chronic pain. On the contrary they observed that, the more exercise performed, the fewer the pain complaints or visible/audible expression of pain.

We showed that 46% of 42 patients with chronic pain demonstrated no significant trend for pain scored on a 10-point visual analog scale during submaximal exertion on a cycle ergometer¹²⁴. Five percent of the subjects presented with a negative trend for pain scores and 49% with a positive trend indicating pain enhancement during exercise. Interestingly, 72% of the female patients and only 33% of the males showed a positive trend. Nevertheless, we found no significant relation between the trend of pain scores and physical fitness index suggesting that exercise-induced pain does not play a major role in the development of deconditioning.

In a first study on pain induced by a maximal treadmill aerobic fitness test, Wittink et al.¹⁸⁶ reported that 54% of 75 patients with chronic low back pain stopped the test because of pain intensity. In another study on exercise-induced pain, the same investigators¹⁸⁵ estimated the aerobic fitness of 75 patients with chronic low back pain through a maximal symptom-limited treadmill exercise test. Although the maximal treadmill test increased pain scores very significantly in most subjects, no relation was found between pre- and post-test pain scores and aerobic fitness.

Interestingly, they found no relation between total duration of pain and aerobic fitness indicating that the severity of deconditioning is not related to chronic pain syndrome duration. The authors concluded that being fit does not protect one from pain enhancement during exercise. In the same study, Wittink et al. also studied the effects on aerobic fitness and pain of a 6-week progressive exercise program with behavioral modification on 17 of the initial 75 patients. Pre- and post-pain were significantly reduced by the program. Maximal performance during the test (time walked in minutes) was also very significantly increased. However, CRE indices remained unchanged suggesting that the results were obtained mostly through behavioral changes rather than through actual physical reconditioning.

The results of many studies suggest that most patients with pain are able to exercise at reasonable intensity levels without significant pain enhancement^{87, 131, 146}. Moreover, participating in physical activities without significant pain increase can successfully modify a patients' mistaken beliefs that exercise is systematically linked with pain¹³¹.

In summary, the link between moderate physical activity and pain is weak if not nonexistent in most patients with pain. Patients with chronic pain are generally able to perform most activities of every day life and are able to participate in well-conducted graded-exercise programs. Maximal exertion may, however, produce very significant pain enhancement. Fitness is not related to pain levels, indicating that activity avoidance may not be explained by activity-related pain.

3.8. PHYSICAL EXERTION AS PERCEIVED BY PATIENTS WITH CHRONIC PAIN

Schmidt reported that patients with chronic low back pain were not able to correctly estimate their level of exertion and were inclined to overestimate their actual individual effort ¹⁴⁵. On the basis of such an observation it may be hypothesized that a systematic overestimation of exercise intensity could lead patients with chronic pain to avoid more intense physical activities and that such a mechanism could play a role in the onset of physical deconditioning.

Very few studies have addressed the issue of exertion perception in patients with chronic pain. We developed an original exertion perception index that can be calculated from rate of perceived exertion (RPE) scores obtained on a 10-point Borg scale during a submaximal cycle ergometer test¹²⁴. This index, the RPE_{65%}, corresponds to the RPE score that a subject would report if he were exercising at an intensity corresponding to 65% of his HR-reserve. It reflects thus exertion perception at moderate submaximal intensity.

We evaluated CRE and exertion perception as reflected by the RPE_{65%} in 42 patients with chronic pain (88% of the subjects had back pain with and without radicular pain) as compared to an age- and sex-matched control group ¹²⁴. While CRE was found very altered in the male patients only, exertion perception was found to be normal in patients of both genders.

We conducted another cross-sectional study aimed at evaluating fitness and exertion perception in female patients with fibromyalgia as compared to controls ¹¹⁸. Contrary to patients with chronic back pain, females with fibromyalgia present with a very significant distortion of exertion perception. During exertion at an intensity corresponding to 65% of HR-

reserve, normal females and female patients with fibromyalgia reported mean scores of 4,9 ('somewhat hard to hard') and 8,2 ('very hard' to 'very very hard'), respectively. Our results do not support the hypothesis that exaggerated exertion perception may generate activity avoidance in female patients with fibromyalgia since fitness level of such patients was found to be normal. We hypothesized that exertion perception and pain are two concepts that partly overlap at high exercise intensity and that the transition zone where exercise becomes painful may extend down to lower exercise intensities in fibromyalgia. The hypervigilance phenomenon that has previously been described may also play an important role in such a distorted exertion perception.

Our observation should be taken into account when prescribing an exercise program which uses the Borg scale as a help to self-monitoring of exercise intensity in patients with chronic pain.

In summary, most patients with low-back pain and/or sciatica perceive submaximal exertion normally. Females with fibromyalgia clearly show a significant distortion in their perception of exertion. During submaximal exercise they report scores on a 10-point Borg scale that are in average 3.3 points higher than healthy controls. Overlap between exercise and pain perception as well as hypervigilance to bodily sensations may explain such a phenomenon.

GENERAL CONCLUSION

The physical capacity (physical fitness) of patients with chronic pain may be affected to variable extent. Job loss is often a determinant factor leading to a reduced level of physical activity, especially in male patients. The fact that males seem more severely affected is probably explained by socio-cultural factors, since males systematically lose more strenuous occupations and become less active at home. Nevertheless, the way chronic pain affects physical capacities is highly variable since many other factors may also intervene. Hence, there is a clear need for reliable physical fitness assessment as part of the comprehensive evaluation of most chronic pain syndromes. Valid and reliable fitness evaluation is needed to define how much physical reconditioning should be emphasized during rehabilitation. Any major physical capacity deficit must be recognized as fitness is a major determinant of physical function and quality of life, and a minimal level of physical capacity is required in most occupations.

In physical capacity assessments of patients with pain, physical performance should not be mistaken for true physical capacity. Since pain and psychological factors may limit physical performance during any maximal physical test, measures obtained through such testing procedures are psychophysical variables and thus, multidimensional. Unidimensional physical tests should be preferred to isolate actual physical deficits from other possible confounding factors such as fear of re-injury. Physical tests should also be well tolerated by patients with pain, since the tests could usefully be repeated during follow-up. Therefore, physical evaluation of patients with pain should probably be limited to CRE, since it is the only

fitness component that can be reliably estimated by submaximal well-tolerated tests. The fact that CRE is generally considered to be the most fundamental component of fitness is another argument for limiting fitness assessments to submaximal CRE testing.

Physical reconditioning programs improve the physical function and quality of life of most patients with pain. Obviously, any well-conducted exercise program should systematically lead to physical capacity improvements in previously deconditioned patients. Moreover, if physical reconditioning is associated with education, the gains in terms of function and quality of life may be greatly increased. Exercise programs may be considered and conceived as a unique opportunity to confront patients with feared exercises and physical activities in general. They will lead not only to true physical capacity improvements, but also to significant behavioral modifications if proper education is provided. Exercise combined with education may have a profound synergic effect that can lead to a reversal of the vicious cycle described by Vlaeyen and Linton ¹⁷² as a mechanism leading to chronic pain. It may be concluded that, in patients with pain, improvements obtained through well-conducted physical reconditioning programs are explainable by both physical and psychological mechanisms. Both the physical and the psychological dimensions should be addressed during comprehensive evaluations through valid, reliable and unidimensional tools, before and during rehabilitation.

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