STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH
154

Marjo Rinne

Effects of Physical Activity, Specific Exercise and Traumatic Brain Injury on Motor Abilities

Theoretical and Pragmatic Assessment

JYVÄSKYLÄN YLIOPISTO

STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH 154

Marjo Rinne

Effects of Physical Activity, Specific Exercise and Traumatic Brain Injury on Motor Abilities

Theoretical and Pragmatic Assessment

Esitetään Jyväskylän yliopiston liikunta- ja terveystieteiden tiedekunnan suostumuksella
julkisesti tarkastettavaksi yliopiston Agora-rakennuksen salissa Ag Aud 2
lokakuun 2. päivänä 2010 kello 12.

Academic dissertation to be publicly discussed, by permission of
the Faculty of Sport and Health Sciences of the University of Jyväskylä,
in building Agora, Auditorium 2, on October 2, 2010 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2010

Effects of Physical Activity, Specific Exercise and Traumatic Brain Injury on Motor Abilities

Theoretical and Pragmatic Assessment

STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH 154

Marjo Rinne

Effects of Physical Activity, Specific Exercise and Traumatic Brain Injury on Motor Abilities

Theoretical and Pragmatic Assessment

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2010

Editor
Harri Suominen
Department of Health Sciences, University of Jyväskylä
Pekka Olsbo, Sini Rainivaara
Publishing Unit, University Library of Jyväskylä

Cover picture by Sanna Korkee, UKK Institute for Health Promotion Research

URN:ISBN:978-951-39-4036-2
ISBN 978-951-39-4036-2 (PDF)

ISBN 978-951-39-4021-8 (nid.)
ISSN 0356-1070

Jyväskylä University Printing House, Jyväskylä 2010

ABSTRACT

Rinne Marjo
Effects of Physical Activity, Specific Exercise and Traumatic Brain Injury on Motor Abilities. Theoretical and pragmatic assessment
Jyväskylä: University of Jyväskylä, 2010, 86 p.
(Studies in Sport, Physical Education and Health
ISSN 0356-1070; 154)
ISBN 978-951-39-4036-2 (PDF), 978-951-39-4021-8 (nid.)
Finnish summary
Diss.

The aims of this dissertation were: (i) to construct a test battery to assess motor abilities among adults, (ii) to study the sensitivity and specificity of the tests in clinical application among men with mild traumatic brain injury (TBI) and their healthy controls, (iii) to create a systematic theoretical evaluation of motor abilities in commonly practised exercise modes, and (iv) to ascertain how leisure time physical activities (LTPA) and specific exercising are associated with motor abilities among age group of 41-47 years.

The consistency of ten motor performance tests was examined in Study I (n=25), Study II (n=70) with test-retest design. The consistency was found to be high or moderate in most of the tests (coefficient of variation 2-15%). Study III, the cross-sectional study of the men with TBI (n=34), showed that they had more impairments in agility, balance and rhythm coordination than the control group (n=36). The best sensitivity and specificity were found in the figure-of-eight run and the probability of detecting motor deficits was also high in other tests. The theoretical evaluation of 30 exercise modes in terms of motor abilities was conducted with eight experts by a nominal group technique aiming at consensus statement (Study IV). The statement suggested that walking, cycling, swimming and jogging require the fewest motor abilities while roller skating, downhill skiing and martial arts require most.

In Study V LTPA of middle-aged men (n=69) and women (n=79) the higher intensity of recent LTPA expressed as metabolic equivalent (MET) hours per week correlated strongly with static balance and agility, and in most tests was associated with a higher test result. The strongest predictor for high motor performance among men was an exercise history of playing ball games, and among women that was former LTPA of several years' duration. Women with higher intensity of recent LTPA attained faster walking time in the dynamic balance, and those with neuromuscular training jumped vertically higher.

In conclusion, the proposed test battery was repeatable and feasible. Even in a clinical setting it provides physiotherapists with basic tools to detect motor deficiencies. A variety of less demanding exercise modes are available for sedentary middle-aged people to start exercising but with higher intensity of LTPA and specific exercise modes higher results in motor performance are achieved. Versatility of specific training and ball games enhances motor abilities.

Key words: motor ability, motor performance, physical activity, exercise, sports, brain injuries, adult, middle aged

Author´s address Marjo Rinne
UKK Institute for Health Promotion Research
P.O.Box 30
FIN-33501 Tampere, Finland
e-mail marjo.rinne@uta.fi

Supervisors Professor Esko Mälkiä
Department of Health Sciences
University of Jyväskylä
Jyväskylä, Finland

Adjunct Professor Seppo Miilunpalo
Kiipula Centre of Vocational Education and Rehabilitation
Turenki, Finland

Reviewers Professor Audrey Hicks
Department of Kinesiology
McMaster University
Ontario, Canada

Adjunct Professor Kari Kauranen
Faculty of Health Care and Social Services
Saimaa University of Applied Sciences
Lappeenranta, Finland

Opponent Professor Mark Tremblay
Faculty of Medicine
Children's Hospital of Eastern Ontario Research Institute
University of Ottawa, Canada

ACKNOWLEDGEMENTS

This research was carried out at the UKK Institute for Health Promotion Research in Tampere, Finland in collaboration with the University of Jyväskylä. The clinical application forming part of this dissertation was conducted in Käpylä Rehabilitation Centre in Helsinki, Finland, whose co-operation is gratefully acknowledged.

The idea to examine motor abilities emerged from a study project named "Determinants of Health-Enhancing Physical Activity Behaviour". First of all I would like to thank Adjunct Professor Seppo Miilunpalo, M.D., Ph.D. for providing me with a chance to do the dissertation as a part of the project, and for consenting to be my supervisor. He has encouraged and supported me in my research work from the very beginning and also contributed in many ways to the preparation of the manuscripts. I am also most indebted to my supervisor Professor Esko Mälkiä, PT, Ph.D., University of Jyväskylä, whose excellent guidance has enabled me to complete this dissertation. He has enhanced my understanding of the ICH model, physical activity and metabolic equivalent (MET), and demonstrated the need to specify terms and explicate them understandably. We have had numerous stimulating discussions concerning physiotherapy, rehabilitation and science. Professor Mälkiä also tutored me in Nordic and international organizational activities in the fields of rehabilitation and physiotherapy, which I most sincerely appreciate.

I express my deepest gratitude to Matti Pasanen, M.Sc. for his most valuable advice and guidance in the world of statistics. He was always available whenever his professional help was needed. In addition to being a proficient co-author he has given me support and confidence to overcome some distress during the process. I am also very grateful to my other co-authors: Pekka Oja, Ph.D., Professor Ari Heinonen, Ph.D., Jaana Sarajuuri, Lic.Psych., Matti Vartiainen, M.Sc., Tommi Lehto, PT, and the late Professor Hannu Alaranta, Ph.D. to whom I express my most profound gratitude for tutoring me in the earlier stages of my research work. I honour his memory.

I am extremely grateful to my official reviewers Professor Audrey Hicks, Ph.D. and Adjunct Professor Kari Kauranen, Ph.D. for careful preliminary examination of the dissertation. Their constructive comments were valuable in finishing the manuscript.

I thank Adjunct Professor Jaana Suni, Ph.D. for sharing her experiences concerning the earlier development work of assessing health-related fitness. The discussions and comments on the consistency problems have been fruitful. My sincere appreciation goes to Ritva Nupponen, D.Soc.Sc. for the exchange of thoughts and her guidance in rendering comprehensible the ambiguous terminology. I am grateful to Emeritus Professor Ilkka Vuori, Ph.D. the former director of the UKK Institute for enabling me to embark on this dissertation.

I also owe thanks to Teija Lempinen, PT, and Marja Kangaspusu, PT for their competent data collection in Study I and Sanna Roine, M.Sc. in Study V.

Special thanks are due to Birgitta Järvinen, M.A. and Mrs Outi Ansamaa for their assistance in library service. Warmest thanks also to Mrs Riitta Pasanen for providing her wide expertise especially for table layouts and word processing problems. Each and every one of you has been exceptionally helpful and lightened up my busy days with your friendliness and sparkling sense of humour.

My sincere thanks go to the entire personnel at the UKK Institute. Your assistance, collaboration and encouraging atmosphere have been inspiring. I want especially to thank Erja Toropainen, M.Sc. and Annika Taulaniemi, M.Sc. I could not wish for better colleagues.

I am grateful to all the participants in my studies. Their contribution has been the base of my work. I also wish to express my gratitude to the panellists who joined the Nominal Group. Your expertise was invaluable to conduct that study. My warm thanks are due to Virginia Mattila, M.A. for her skilfull revision of English language of the dissertation.

Warm thanks are also due to my best friend, Eeva-Helena. Our friendship has lasted from the very first school day and I hope it will continue “for ever and a day”. We have shared so much together.

This study was financially supported by the Ministry of Education, Finland and through a grant from the National Graduate School of Musculoskeletal Disorders and Biomaterials (TGBS). They are gratefully acknowledged.

My dearest brother Riku, I give my warmest thanks to you. We have a strong bond and we have much in common, not least music. I know that I can always trust you whatever happens in my life. I am extremely grateful to my late grandparents Kerttu and Veikko Manner. My grandmother raised me to respect humanity and also the importance of education. My grandfather Veikko, “Taata”, motivated me to refine my motor abilities in sports ever since my youth. He was also for me the kindest and most harmonious tower of strength and experience of life. He would have liked to see me achieve this goal.

I dedicate this dissertation to my family. First, I would like to express my loving thoughts to Pauliina and Carita, my nearest and dearest daughters. You have made my life enjoyable and filled it with happiness. You have kept my feet on the ground, thoughts on everyday matters and shown me what is important in life. I have learned much from you. Finally, Timo, my dearest, I appreciate your being there sharing my joys and worries. You are the most important person in my life. You have empowered my dissertation in many ways by taking care of many other practical things in everyday life while I concentrated on this work. Thank you with my all heart, just for everything that has been and is to come.

FIGURES

TABLES

LIST OF ORIGINAL PUBLICATIONS

I Rinne MB, Pasanen ME, Miilunpalo SI, Oja P. 2001. Test-retest reproducibility and inter-rater reliability of a motor skill test battery for adults. Int J Sports Med 22 (3), 192-200.

II Vartiainen MV, Rinne MB, Lehto TM, Pasanen ME, Sarajuuri JM, Alaranta HT. 2006. The test-retest reliability of motor performance measures after traumatic brain injury. Advances in Physiotherapy 8 (2), 50-59.

III Rinne MB, Pasanen ME, Vartiainen MV, Lehto TM, Sarajuuri JM, Alaranta HT. 2006. Motor performance in physically well-recovered men with traumatic brain injury. J Rehabil Med 38 (4), 224-229.

IV Rinne MB, Miilunpalo SI, Heinonen AO. 2007. Evaluation of required motor abilities in commonly practised exercise modes and potential training effects among adults. Journal of Physical Activity and Health 4, (2) 203-214.

V Rinne M, Pasanen M, Miilunpalo S, Mälkiä E. 2010. Is generic physical activity or specific exercise associated with motor abilities? Med Sci Sports Exerc 42 (9), 1760-1768.

ABBREVIATIONS

ANCOVA	Analyses of covariance
ANOVA	Analyses of variance
AUC	Area under curve
BMI	Body mass index (weight in kg divided by height in m^2)
C	Control group
CAT	Computerized adaptive testing
CNS	Central nervous system
CV	Coefficient of variation
FAM	Functional Assessment Measure
FIM	Functional Independence Measure
F-LTPA	Former leisure time physical activity
fMRI	Functional magnetic resonance imaging
GMR	Geometric mean ratio
HRF	Health related fitness
ICC	Intraclass correlation coefficient
ICF	International Classification of Functioning, Disability and Health
κ	Kappa coefficient
km	Kilometer
LTPA	Leisure time physical activity
M_1	Metabolic equivalent value for activity
max	Maximal
MET	Metabolic equivalent
METh	Metabolic equivalent hour
$METh \cdot wk^{-1}$	Metabolic equivalent hour per week
min	Minute
ml	Millilitre
MPAR-Q	Modified Physical Activity Questionnaire
M.Sc.	Master of Science
n	Number of subjects
NG	Nominal group
OR	Odds ratio
p-value	Probability of obtaining a test statistic at least as extreme as that actually observed, assuming that the null hypothesis is true.
PA	Physical activity
Ph.D.	Doctor of Philosophy
PNS	Peripheral nervous system
R_S	Spearman´s rank correlation coefficient
R-LTPA	Recent leisure time physical activity
ROC	Receiver operating characteristics
ROM	Range of movement
s	Second
SD	Standard deviation

t_1	Duration of activity as hours
TBI	Traumatic brain injury
UKK	Urho Kaleva Kekkonen
U.S.	United States
VO_{2max}	Maximal oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)
WHO	World Health Organisation

CONTENTS

1 INTRODUCTION

Habitual physical activity (PA) and exercising have many beneficial effects on health and are a key factor in the primary and secondary prevention of health problems, chronic diseases and age-related loss of functional capacity [World Health Organization (WHO) 2004, U.S. Department of Health and Human Services 2008, Warburton et al. 2010]. However, beyond the age of 40 the amount and intensity of PA or specific sport activities decreases and sedentary behaviour increases with adverse effects on health, physical fitness and motor performance (Hagströmer et al. 2007, Helakorpi et al. 2010).

Motor abilities are the foundation of human locomotion and functioning. Maintenance of upright posture, movements of the trunk with countermovements of the extremities, and postural balance of the body are necessary for walking, running and jumping, thus the ability to move (Burton & Miller 1998, Magill 2004). All these functions are developed in the early years of childhood and during maturation, and learnt and trained by doing (Fleishman 1967). Variability in human movement systems helps individuals adapt to unique tasks and environments (Davids et al. 2003). Motor abilities are considered to be relatively enduring characteristics and related to performances in a variety of human tasks (Fleishman 1967, Fleishman & Quaintance 1984, Magill 2004, Schmidt & Lee 2005). They are determinants and controllers of performance but also components of physical fitness which are needed to perform physical activities and exercises (Fleishman & Quaintance 1984, Hirtz 1985, Magill 2004). Definitions such as spatial orientation, kinaesthetic differentiation, static and dynamic postural balance, sense of rhythm, agility, and in addition, multilimb coordination, precision, timing, and aiming have been widely used (Fleishman 1967, Fleishman & Quaintance 1984, Hirtz 1985, Burton & Rodgerson 2001, Magill 2004, Schmidt & Lee 2005).

The interest in assessing motor abilities has mostly been focused on children (Hirzt 1985, Burton & Rodgerson 2001, Magill 2004). Motor abilities have been considered to reach maturation by the age of 16. Furthermore, motor abilities in school-age have been found to influence participation in sports (Tammelin 2005, van der Horst et al. 2007). Through ageing and illness human movement systems tend to show a loss of adaptation to complex tasks and to environmental demands and this may cause reduced functional capacity (Davids et al. 2003). Alternatively, among adults it has been deemed increasingly important to measure the components of fitness because the significance of physical activity (PA) with respect to health and physical functional status has increased (Haskell et al. 2007, U.S. Department of Health and Human Services 2008). The concept of health-related fitness (HRF) has been introduced as the Toronto model, and its main components are aerobic capacity, muscular (strength and flexibility), and motor fitness (Bouchard et al. 1994). However, motor fitness is considered in this concept mainly as postural balance. Generally the assessment of HRF has been aimed more at enhancing leisure time physical activity (LTPA) and the physical activity of middle-aged population (Suni et al. 1999).

LTPA in various exercise modes is recommended in order to improve fitness and maintain health, to reduce the risk of chronic diseases and disabilities, and to prevent unhealthy weight gain (Haskell et al. 2007, U.S. Department of Health and Human Services 2008). Earlier research and recommendations on health-enhancing LTPA have mainly focused on aerobic-type exercise and its appropriate frequency, intensity and amount (Pate et al. 1995).

Recent updates of recommendations also emphasize the importance of muscle-strengthening activities, and, complementary to previous recommendations, balance training for the elderly is pointed out (Haskell et al. 2007, U.S. Department of Health and Human Services 2008, Warburton et al. 2010). Consequently, training of motor abilities has emerged in intervention studies on the prevention of osteoporotic fractures and falls, and decline in physical functioning (Karinkanta et al. 2007, Madureira et al. 2007). These studies suggest that people who are more active have on average better postural balance, faster reaction time, and a slower rate of motor decline in mobility function. Nevertheless, evidence of different LTPA modes effective for motor abilities is the scarcest.

The starting point for this dissertation was a larger project in which the main focus was on determinants of physical activity and behavioural principles, and the study aim was to provide useful applications for health and exercise promotion (Marttila et al. 1998, Miilunpalo et al. 2000). Accordingly, physical activities were considered behaviourally versatile. For a beginner some of them are relatively easy to start while others may be complex and therefore difficult to adopt and maintain. Therefore it is essential to identify the preconditions for physical activities which make them feasible and long-lasting. One of those preconditions is motor abilities.

In the fields of physiotherapy and rehabilitation different features of motor performance are usually assessed separately and the tools may be difficult to use and time consuming (Finch et al. 2002, Jette et al. 2008, Jette et al. 2009). However, in WHO International Classification of Functioning, Disability and Health (ICF) has been developed to provide a concept to combine different components of functioning (WHO 2001). Problems in motor performance are most evident with neurological patients but most of the motor performance tests are not standardized for screening motor abilities as a whole (Jette et al. 2009). In conventional neurological examinations the findings may be normal but patients may still experience undefined symptoms. This is the case, for instance, among physically well-recovered patients with traumatic brain injury (TBI). TBI is known to cause a diversity of disorders involving motor performance (Dombovy & Olek 1996, Masanic & Bayley 1998, Quinn & Sullivan 2000). These subjectively experienced symptoms may occur when patients return to premorbid activities, sport or work. Although the problems in motor performance are observed clinically, it is not clear how to assess motor performance. Assessing the motor performance of patients with TBI will help to understand wider connections and mechanisms between neurophysiologic functions and motor abilities. So far no generally accepted standardized motor performance screening tests for adult patients with TBI are available for clinical use.

This dissertation proceeded in several stages. The first stage was to develop a test battery to assess the motor abilities of middle-aged adults and physically well-recovered male TBI patients and to examine the consistency of tests. The second stage was to compare motor abilities between the TBI patients and healthy controls and to establish sensitive, specific and valid cut-off values of respective motor performance measures for clinical use. At the third stage motor abilities in different exercise modes were evaluated theoretically to give a basis that indicates the most important motor abilities and physical fitness components that should be considered when counselling sedentary adults to select adequate exercise modes. Finally, the last stage expanded the view of recent updates of guidelines for adults in terms of motor abilities and some physical fitness components in relation to physical activity (Haskell et al. 2007, U.S. Department of Health and Human Services 2008).

2 REVIEW OF THE LITERATURE

2.1 Essence of motor abilities

Motor behaviour has been considered to be important to human actions and movements in different physical activities, and everyday tasks. The interest to assess motor performance was aroused in physical education, and the earliest studies could be tracked back in the 1920s. Then D.A. Sargent created the "Physical Test of Man" which was an index of vertical jump. He stated that it was "the simplest and most effective of all tests of physical ability" (Sargent 1921). The idea was that so called general motor ability could be measured with a single test.

However, other researchers subsequently studied different elements of physical abilities, such as standing, kicking, jumping, hopping, squatting, bending, throwing and so forth (Bruininks 1978, Reed & Metzker 2004, Bruininks & Bruininks 2006). These studies were carried out among school-aged children and the aim was to obtain scores of successfully performed trials to represent a general motor ability.

2.1.1 Concepts of motor abilities

The concepts of motor abilities have been generated from different perspectives. Psychologists have been interested in motor behaviour and many psychomotor tests were developed to measure both mental and motor functions in different work tasks (Fleishman 1964). Basically, the aims of these tests were to measure visual acuity, reaction time, accuracy, speed, coordination, and success in complex tasks resembling the demands in different jobs. The concepts of ability and skill were distinguished. The assumption was that the skills involved in complex tasks could be described in terms of multiple basic abilities (Fleishman 1967). Accordingly, Fleishman (1964) drew on the previous methodological framework, which was used for classifying human tasks in context with psychomotor factors, and studied physical fitness and performance tests in terms of the factors they were presumed to measure. The common physical fitness tests were complemented with the motor performance tests which measured speed, flexibility, balance and coordination (Fleishman 1964 and 1967).

In the 1970´s a theoretical framework was also conducted in the German-speaking countries. Hirtz (1985) published a review in which he synthesized the most significant studies in the field of physical education concerning physical fitness and motor performance. He stated that the elements of physical capacity are composed of three main components, namely physical fitness, motor readiness (maturity) and coordinative ability. The concept of coordinative abilities (Koordinative Fähigkeiten) included the cognitive processes and consists of five different abilities. These abilities were specified as reaction ability, sense of rhythm, balance, spatial orientation and kinaesthetic differentiation. This was also the theoretical background for how to practice abilities in physical education (Bös 1987).

Textbooks on motor abilities and skills give definitions of movement skills, motor abilities and general motor ability, which reflects the prevalent opinion of the concepts (Burton & Miller 1998, Magill 2004, Schmidt & Lee 2005). The conceptual hierarchy is that general motor ability is the most basic level of abilities, above this is motor ability and the highest level is movement skill.

In addition, Burton and Rodgerson (2001) expressed their opinion about the concept of motor abilities and movement skills concerning adapted physical education. They recommended a new taxonomy to replace those used in the textbooks. The taxonomy was intended to organize the assessment instruments, and the authors' proposal was: The first and second levels are movement skills and movement skill sets which are considered according to functions and replace the concept of multiple motor abilities (Magill 2004, Schmidt & Lee 2005). The third level is the movement skill foundation and these are skill specific, such as riding a bicycle. The fourth level is the general motor ability, which relates to variation between the performer and environmental factors (Burton & Rodgerson 2001). However, this taxonomy is more like a theoretical tool and the authors offer no new or specific instruments for assessing motor skills.

In summary, most of the conceptualizing has focused on children in terms of physical education and constituted a basis to understand motor learning and to develop teaching. No attempt has been made to account for the theoretical background with regard to adult population. Furthermore, the terminology concerning motor behaviour, motor/psychomotor/perceptual motor abilities, motor/movement skills, motor control, and motor performance is still a mixture of terms from psychology and physical education. The use of these words in the scientific literature is also inconsistent and there seems to be no consensus on wording. In this dissertation the term motor ability is designated as a key term and will be defined more precisely below.

2.1.2 Determination of motor ability and disability

The term ability basically refers to psychology, where it has been used in the studies of individual differences in terms of characterising and differentiating individuals. In this context motor ability has been considered as ability related to the performance of specific skills. However, Fleishman (1967) distinguishes the terms ability and skill. He stated that the term ability refers to a more general trait of the individual, while abilities are a fairly constant trait and difficult to change. The effects of learning, environmental and cultural factors, and possible lifelong development were considered concurrently (Fleisman & Quaintance 1984, Hirtz 1985). Motor abilities also include information processing in the brain, and coordination of a sensory or cognitive process and motor activity, which makes the interpretation more complex.

The terms single and general motor ability have also been used. Although motor abilities have been considered to be relatively independent, a person may have many advanced basic abilities and become skilled at a variety of specific tasks. Consequently, this indicates that when a person has several advanced single motor abilities, he or she may be talented in all motor skills. Alternatively, the skills which are needed in complex activities can be described in terms of the basic abilities.

The terms functional ability, and functioning and disability have also been used in physiotherapy when measuring motor abilities. Disability has a more extensive meaning and also refers to the gap between a person's abilities and environmental demands (Nagi 1965, Verbrugge and Jette 1994). In the ICF model (WHO 2001) functioning and disability comprise 2 components: one of them is body functions and structures, and another is activities and participation. Domains of component of activities and participation are qualified by performance and capacity. The first qualifier is performance, which can be understood as involvement in an actual context of life situation, and also includes environmental factors. The second qualifier, capacity, describes an ability to execute a task or an action. Capacity is commonly assessed in standardized test settings and indicates the highest achievable level of functioning that an individual can reach at that moment. In the ICF model the term disability complements functioning and also encompasses impairments, limitations in activities, and restrictions in participation (WHO 2001, Stucki et al. 2007).

In the context of this dissertation motor abilities are considered to be separate, relatively independent of one another, and to underlie motor performance. A person has many motor abilities and these can differ in their proficiency levels, which may indicate limits or potentiality in motor performance.

2.1.3 Classification of motor abilities

Efforts have been made to understand basic abilities both according to a theoretical framework and extensive batteries of perceptual motor tests.

Fleishman (1964) conducted factor analyses in order to define the fewest independent ability categories describing human motor performance in different tasks. According to these studies, 11 psychomotor factors and 9 physical proficiency factors, i.e. physical fitness, were found. Hirtz (1985) also conducted factor analyses in order to find coordinative psychomotor abilities related to sports and physical education. Accordingly he classified the motor abilities into five categories. Both Fleishman´s (1964) and Hirtz`s (1985) classifications and definitions are summarized in Table 1.

The final statements of both authors are quite similar, although they used different terms. Fleishman was more interested in perceptual and fine motor abilities. However, he also studied physical fitness components naming them gross motor performance. Hirtz (1985) combined single abilities in terms of describing motor performance as an aggregate, and, in addition, also included the same factors in coordinative abilities that Fleishman regarded more or less as "physical proficiency abilities". The features of motor abilities can be found in both.

TABLE 1 Classifications and corresponding definitions of psychomotor abilities and physical proficiency according to the factor analyses (Fleishman 1964, Hirtz 1985).

Fleishman		Hirtz	
Psychomotor abilities			
Control precision	Highly controlled arm/hand and leg movements	Kinaesthetic differentiation	Ability to process auditory, visual and tactile information; ability to feel tension in movement to achieve the desired movement; ability to choose movements, strength needed, distance and timing appropriate to the task.
Multilimb coordination	Coordination of movements of limbs simultaneously	Spatial orientation	The control and coordination of the body in space; to sense posture and movement in relation to space and timing.
Response orientation	Rapid directional discrimination and orientation of movement patterns under highly speeded conditions	Reaction ability	To respond quickly to auditory, visual and kinaesthetic cues; the time from the onset of the signal to the completion of a response, includes reaction and movement times.
Reaction time	The speed with which the individual responds to a stimulus	Sense of rhythm	Synchronization of movements in time - unrelated limb movements completed in a synchronized manner
Speed of arm movement	Gross, discreet arm movement, accuracy is not the requirement	Balance	Maintenance of the centre of gravity over the base of support in different postures and movements. It has a static and a dynamic quality
Rate control	Motor adjustment relative to changes of moving object		
Manual dexterity	Well-directed arm-hand movements under speed conditions		
Finger dexterity	Skilful, controlled manipulations of tiny objects with fingers		
Arm-hand steadiness	Precise arm-hand positioning movements, with minimized strength and speed		
Wrist, finger speed	Rapid "tapping" with hands		
Aiming	Eye-hand coordination		

(continues)

TABLE 1 (continues)

Physical proficiency (fitness)	
Extended flexibility	To stretch trunk and back muscles as far as possible
Dynamic flexibility	The ability to make repeated rapid flexing movements
Explosive strength	One or a series of explosive acts with maximum energy, like Broad Jump or Softball Throw test
Static strength	Maximum force against external objects for a brief period
Dynamic strength	Muscular endurance, resistance of muscles to fatigue
Trunk strength	Dynamic strength, specific to the trunk muscles
Gross body coordination	The ability to coordinate movements of body parts while making gross body movements
Gross body equilibrium	The ability to maintain postural balance despite disturbing forces
Stamina	Capacity of cardiovascular functions, endurance

In this dissertation the framework was created on the basis of a literature review which produced a synthesis of previously presented concepts, determinations, and classifications of motor abilities (Fleishman 1964, Fleisman & Quaintance 1984, Hirtz 1985, Burton & Rodgerson 2001, Magill 2004). The motor abilities adapted to this framework are compiled with their corresponding definitions in Table 2.

TABLE 2 The definitions of motor abilities (Rinne et al. 2007).

Motor ability	**Definition**
Orientation	To sense posture and movement in relation to space and timing, and to coordinate these in an appropriate way
Kinaesthetic differentiation	To process the auditory, visual and tactile information To anticipate and to control the muscles in relation to needed strength, distance and timing
Postural balance * static *dynamic	To maintain and obtain equilibrium in different postures and movements and centre of gravity over base of support
Reaction ability	The time from the onset of the signal to the completion of a response, includes both reaction and movement times
Rhythm coordination	The use of timing and coordination in fluent movement and performance

Figure 1 presents the framework of the dissertation, the main focus being on motor abilities. In this framework perceptual and proprioceptive functions refer to physiology and to the specific sense perceptions, which contribute to the initiation and control of movements (Fleishman 1964, Fleishman & Quaintance 1984, Hirtz 1985, Magill 2004). These are the base for single motor abilities, which in turn are activity and task based. Accordingly, motor performance is the outcome of the combination or variation of different motor abilities. However, physical capacity is also needed when the intensity and/or duration of performance increases. The term motor skill is retained in the framework to illustrate the direction if the specific objective is to train the components target-oriented aiming at a particular motor skill, and, thus, exercise-specific technique.

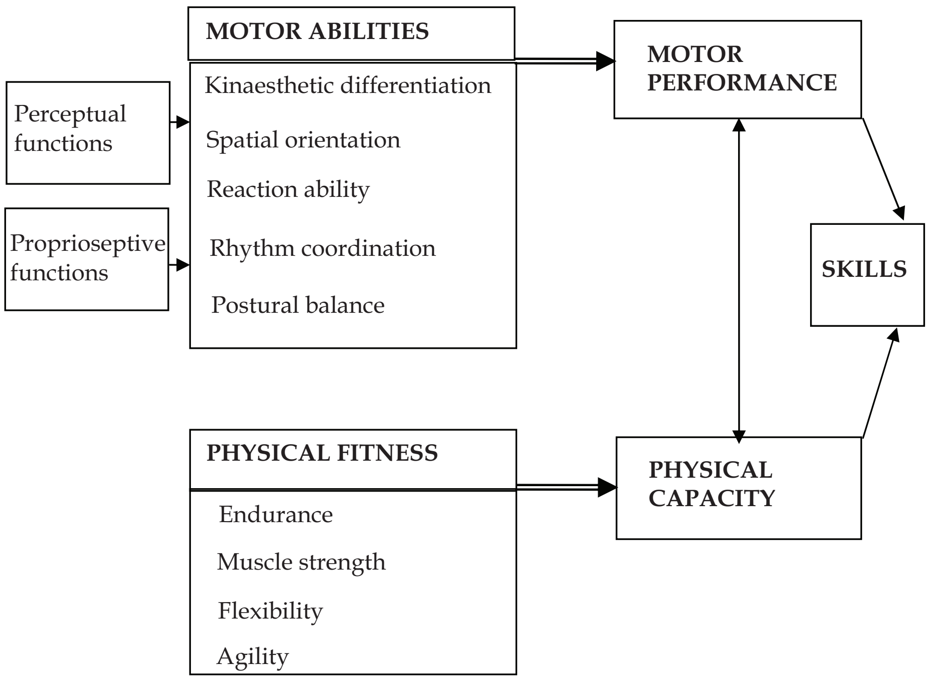


FIGURE 1 Framework of the determinants motor ability, motor performance and physical capacity in relation to skills.

2.1.4 Regulation of motor abilities

Motor abilities are complex and controlled by many brain functions. The human brain consists of 10^{11} neurons forming a cooperating network. The brain continuously receives sensory information, and monitors and regulates the bodily actions and functions. The brain directs motor performance via the primary motor cortex, the supplementary motor area, the premotor and parietal cortex, the basal ganglia and the cerebellum (Serrien et al. 2007).

The cerebral cortex is divided into hemispheres and forms the largest part of the human brain. The neocortex is situated on the top of other brain structures and is the centre of higher functions such as language, memory and learning. The parts of the cortex are called the association areas and they are involved in complex processes such as perception, thought, generation of motor commands and spatial reasoning. In addition, the supplementary motor area is a part of the sensorimotor cerebral cortex and is known to be involved in the planning, initiation and execution of movements (Kandel et al. 2000). The cerebellum is attached to the base of the brain and is responsible for postural balance, postures, and the coordination of movement, and is also involved in some cognitive functions (attention, language) (Wolf et al. 2009). The cerebellum does not initiate movement, but contributes to coordination, precision, and accurate timing (Grahn & Brett 2007, Thaut et al. 2008). Both of these structures are hierarchically the highest organs of the central nervous system (CNS). The spinal cord is a part of the CNS and transmits neural commands from the primary motor area via efferent nerves to the peripheral nervous system (PNS) (Kandel et al. 2000, Afifi & Bergman 2005).

The transmission is always reciprocal. Afferent neurons carry information along nerve impulses from sense organs toward the primary cortex and the interpretation of information always needs former memories. The executive functions of the frontal lobes involve, for instance, the ability to recognize the consequences of present actions and to choose a performance pattern, and determine similarities and differences between things or events. All these reactions occur in a fraction of a second. (Figure 2)

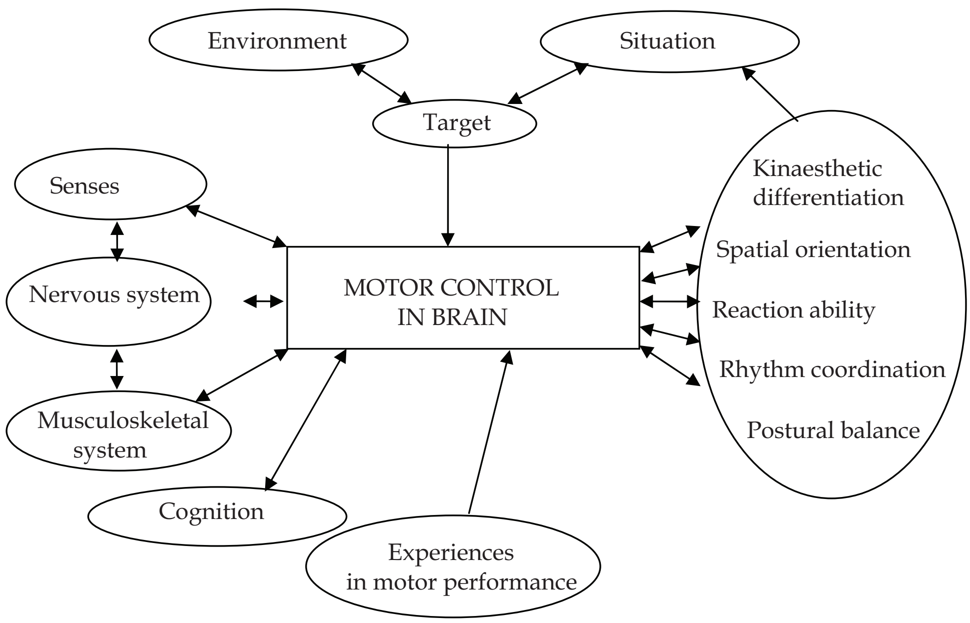


FIGURE 2 Motor abilities and motor performance are the outcome of many functions of the organs and regulated by the brain.

Recently neurosciences have implemented new imaging technologies, e.g. functional magnetic resonance imaging (fMRI) and standardized low-resolution brain electromagnetic tomography. These technologies yield more information about exercise induced brain activation and the function of supplementary motor area in the brain in the planning, initiation, timing and execution of motor acts (Thaut et al. 2008, Schneider et al. 2010). Information processing, attention and executive functioning have been found to be constantly associated with motor performance. The findings lend support to the previous notion that there is interaction between motor performance and cognition (Tanji 1996, Picard & Strick 2003, Serrien et al. 2007, Tankus et al. 2009). For instance, generation of complex movements and the processing of sensory information during the exercise have been found to be associated with overall cortical activation, even inducing activity within a part of secondary visual areas which also seems to be connected to language processing. These studies are preliminary, conducted in laboratories, and not in clinical practice but they increase the understanding of the mechanisms of motor regulation.

One of the applications of fMRI in order to measure motor abilities more precisely has been the examination of auditory stimulus, beat perception and motor response. The images of brain activations during the stimulus ascertain the timing of movement in relation to simple and complex metric rhythms (Chen et al. 2008, Thaut et al. 2008). The acoustic nerve is responsible for transmitting sound and information on postural balance and head position to the brain. The stimulus is mediated via the primary motor cortex to the so-called supplementary motor area and cerebellum and they activate motor regions of the brain. As an outcome of this activation humans have been observed to start spontaneously to nod their heads or tap their feet or fingertips according to the rhythm. Precise timing of movement in relation to simple metric rhythms is more accurately produced than complex rhythms, even with practice (Grahn & Brett 2007, Chen et al. 2008). It seems possible that most humans can perceive a beat because not only musically trained persons but also non-musicians activate these areas. Many exercise modes are based on rhythmic coordinative movements, not to mention all the exercising performed to music (Grahn & Brett 2007).

Serrien et al. (2007) modelled the neural processes in use during complex motor tasks. Accordingly well-learned motor skills are based on a network of primary and secondary sensor motor areas and subcortical regions. During complex skill acquisition, cognitive resources are recruited to ensure that action is performed in accordance with the goal requirements. The frontal lobes of the brain are active and linked to response selection and monitoring. Although the significance of cognitive processes is generally accepted, their underlying mechanisms and interaction with motor circuits are not clear (Serrien et al. 2007). Furthermore, effective coordination of motor abilities and activities involves the complex interaction of the sensory and cognitive process, motor-programming, and the musculoskeletal system (Sosnoff et al. 2008). Even minor impairments in integrating this information can lead to significant disability.

2.1.5 Disability in motor abilities due to traumatic brain injury

Traumatic brain injury (TBI) is a worldwide public health problem and a major cause of disability (Cassidy et al. 2004). The incidence of hospitalized patients with TBI in Finland has been 100 cases/100.000 person-years (Alaranta et al. 2000), in the USA 618 cases/100.000 person years, and in Scotland 326 cases/ 100,000 person years (McGuire et al. 1995, Sosin et al. 1996, Cassidy et al 2004). However, Sosin et al. (1996) reported that only a quarter of all TBI cases are treated in hospitals. Men are at higher risk of TBI (0.88-2.5 times higher than the risk for women) (Cassidy et al. 2004).

The consequences of TBI are many and usually complex. Subjectively experienced physical deficiencies, such as fatigue, impairments in postural balance, difficulties in rapid movements, running, and motor coordination are common disturbances even after recovering from TBI (Ponsdorf et al. 1995, Concensus conference 1999, Quinn & Sullivan 2000). Studies have shown that patients with TBI have deficits in postural balance and coordination, even after successful rehabilitation. These subjectively experienced symptoms may occur when patients return to pre-morbid activities, work or sport (Dombovy & Olek 1996, Masanic & Bayley 1998, Quinn & Sullivan 2000). In addition, people with TBI typically have neuropsychological deficits which affect their ability, for example, to initiate, plan or have energy to participate in physical activities (Bateman et al. 2001). Therefore, a person with TBI may find it even harder to accomplish the activities of daily living which may negatively influence a person's ability to function independently (Bateman et al. 2001).

Studies concerning disability in motor abilities after TBI have mainly focused on postural balance and walking. Postural balance problems are most evident in cases of deep parenchymal brain damage or focal cerebral lesions (Ponsdorf et al. 1995). People with TBI rely on visual input, they may not use their vestibular systems effectively, and they tend to sway more than normal control subjects (Ponsdorf et al. 1995, Geurts et al. 1999, Cantin et al. 2007). Cantin and co-workers (2007) also found that people with TBI walked slower and had higher clearance margins than healthy subjects.

Furthermore, damage or injury to the cerebellum notably causes disorders in fine movement, equilibrium, posture and motor learning. Campbell's and Parry's (2005) study offers support for the proposal that balance dysfunction after TBI has a multisystem basis and appropriate methods of assessment should be developed to enable routine screening. In addition, Geurts et al. (1999) found loss of dynamic postural balance control in weight shifting tasks, and McFadyen et al. (2003) showed that residual effects of TBI on walking persist although general locomotor capacity recovers. Likewise many patients with TBI have difficulties in tasks which require simultaneous rhythmic movements of the upper and lower limbs (Quinn & Sullivan 2000).

Regardless of neurological soft signs and subjective complaints, clear physical findings after TBI may not be apparent in clinical examination and they are also difficult to assess. When physical problems occur after mild or moderate TBI, it has been considered important to identify rapid alternating movements, gait and balance, static/dynamic posture and vestibular system integrity (Quinn & Sullivan 2000).

Even if the need for knowledge and tests measuring the motor performance of physically well-recovered patients with TBI is recognized, only few earlier studies have endeavoured to explore these aspects, and many currently used physical tests may not be sensitive enough to detect the motor problems. Neuropsychological tests have been used to assess the motor functions of the hands (simple and complex forms of praxis) but these have been addressed to measuring information processing, attention and executive functioning but not motor abilities and performance.

2.2 Bases for testing motor abilities and performance

2.2.1 Measures of consistency

In order to develop motor and physical performance tests, several aspects of consistency are important (Atkinson & Neville 1998, Hopkins 2000). The consistency of a test should be studied by repeating the measurement a reasonable number of times on a reasonable number of individuals representing the population for whom they are intended (Atkinsson & Neville 1998, Hopkins 2000).

The development of test procedures needs appropriate and multiple statistical methods. Consistency includes repeatability and reproducibility, and both of these are fundamental characteristics of an acceptable test for clinical practice. Repeatability, also called test-retest reliability, refers to the variation in measurements taken by a single person on the same item and under the same conditions. A measurement is repeatable when the variation is smaller than the agreed limit (Bland & Altman 1986, Läärä & Aro 1988). Reproducibility refers to the ability of a test to be accurately replicated by someone else in different environment with the original experimental description (British Standards Institution 1979, Läärä & Aro 1988). To estimate the consistency of test results statistics such as change in the mean, within-subject standard deviation (also called the standard error of measurement), coefficient of variation (CV), 95% limits of agreement, and retest correlation have been called for (Hopkins 2000).

The difference between the means of two tests is called the change in the mean. It includes both a random change and a systematic change. Random change in the mean occurs due to sampling error and is smaller with larger sample sizes. Systematic change in the mean is a non-random change in the value between two trials and could, for instance, depend on the learning effect. The within-subject standard deviation is the typical error or variation in a subject's value from measurement to measurement. For that reason it is also called the typical error of measurement or typical error. The typical error can also be presented as the CV which expresses changes in the mean between tests as percent changes. Recently the CV has been preferred for comparing data. CV is the ratio of the standard deviation to the mean, and these ratios of different variables can be compared to other such ratios in a meaningful way with different units instead of the standard deviation: the variable with the smaller CV is less dispersed than the variable with the larger CV. A CV value < 15% is considered to have high reproducibility (UCLA, Armitage et al. 2002).

Another form of within-subject variation is the 95% limits of agreement (Bland and Altman plot), which represent the 95% likely upper and lower ranges for the difference between an individual’s scores in two tests (Atkinson & Nevill 1998). The Bland-Altman plot describes the total error between test and retest, gives a rough indication of the systematic and random error, and reveals the heteroscedasticity of the data.

To assess the retest correlation the intraclass correlation coefficient (ICC) is commonly used. It can be used even among smaller samples, but if the sample is homogeneous, the correlation will be weak. In addition, to assess the consistency for the nominal variables, the proper measure is the kappa coefficient. It is analogous to a correlation coefficient and has the same range of values (-1 to +1) although the values are lower then those of ICC (Armitage et al. 2002).

2.2.2 Sensitivity and specificity

Sensitivity and specificity calculations are used to measure the performance of a test to detect the presence of a disease. Sensitivity measures the proportion of actual positive cases correctly identified to have the disease (i.e. probability that a truly diseased person gets a positive test result). On the other hand, specificity measures the proportion of negative test results correctly identified. The highest, optimal prediction can achieve 100% sensitivity, which means that the test identifies all cases in the group of diseased people as ill. If the test does not identify anyone from the healthy group as ill then 100% specificity is achieved (Hulley et al. 2000).

The relationship between sensitivity and specificity can be presented in graphics and studied using a receiver operating characteristic (ROC). In a ROC curve the sensitivity is plotted as a function of the false positive rate (1-specificity) for different cut-off points. Each point on the ROC plot represents a sensitivity/specificity pair corresponding to a particular decision threshold. The closer the ROC plot is to the upper left corner, the higher the overall accuracy of the test. The ROC analysis provides a tool to select possible optimal cut-off points (Hulley et al. 2000, Armitage et al. 2002).

2.2.3 Tests for assessing motor abilities and motor performance

Motor ability, performance and skill tests have mostly been developed for physical education and aimed at school-aged children (Bruininks 1978, Beunen et al. 1997, Baquet et al. 2006, Bruininks & Bruininks 2006). Specific tests for different exercise modes have also been used in coaching competitive athletes, and some test batteries have been designed to assess performance in different occupational tasks. In the past twenty years several functional performance tests have been developed for elderly people to assess and predict functional decline (van Heuvelen et al. 1998, Lemmink et al. 2003, Husu et al. 2007). However, no comprehensive test battery including different aspects of motor abilities and performance is available for general mid-life population. Although the component of motor fitness has been introduced in the concept of health-related fitness, the main focus has been on measuring balance (Bouchard et al. 1994). Good postural balance is essential for the safe performance of mobility activities and more specifically, static and dynamic postural balance are necessary for the safe performance of walking, running and most recreational activities and the ability to perform multiple tasks simultaneously (U.S.

Department of Health and Human Services 2008). For this purpose a large number of balance tests have been developed for field test situations (Tegner et al. 1986, Engström et al. 1993, EUROFIT 1993, Nelson et al. 1994, Risberg et al. 1995, Suni et al. 1996) or for measurements with devices in laboratory settings (Geiger et al. 2001).

In orthopaedics and neurological rehabilitation some motor tests have also been used (Tegner et al. 1986, Fonseca et al. 1992, Risberg et al. 1995, Finch et al. 2002, Jette et al. 2009). Among TBI patients who recovered well after trauma indications of static and dynamic postural balance disturbances, retarded velocity and difficulties in motor coordination have been reported (Geurts et al. 1999, Azouvi et al. 2004). One of the most used balance tests, the Berg Balance Scale, has been found to have high intra-rater and inter-rater consistency, but this test also has limitations due to a ceiling effect for patients with mild neurological deficits (Geiger et al. 2001). Nevertheless, clear protocols and reliable field test methods for assessing motor problems among well recovered TBI patients are still unknown. Quinn & Sullivan (2000) proposed the items to be included in an assessment protocol, e.g. balance with unstable, reduced or changing base of support, gait, coordination and rapid alternating movements. Functional hopping and short distance running tests have been developed in order to monitor rehabilitation after anterior cruciate ligament trauma, but the results of repeatability examination have been inconsistent (Tegner et al. 1986, Risberg et al. 1995).

The tests for rhythm coordination are few. The Seashore Test of Musical Abilities has been implemented in schools of music. This test has been modified for neuropsychological purposes to detect severe brain deficits and is known as the Seashore Rhythm Test (Reitan & Wolfson 1989, Gfeller & Cradock 1998). It requires recognition of similarities and differences in pairs of rhythmic beat but does not measure motor coordination (Gfeller & Cradock 1998).

2.3 Physical activity and exercise in relation to motor abilities and motor performance

2.3.1 Determination of physical activity and exercise

PA has been defined as 'any bodily movement produced by the skeletal muscles that increase energy expenditure' (WHO 2001, U.S. Department of Health 1996). Some decades ago PA and exercise were regarded as synonymous, and their main purpose was to develop aerobic fitness. The terminology has been defined more closely, and nowadays PA and exercise are understood more distinctly. Both are also considered important factors for health promotion and disease prevention due to the evidence indicating a lack of physical activity (physical inactivity) as an independent risk factor for chronic diseases.

PA can be expressed according to mode, intensity, and purpose (U.S. Department of Health and Human Services 2008). Mode refers to the type of activity. Intensity can be displayed in absolute or relative terms. Absolute intensity refers to the rate of energy expenditure [(e.g. $ml \cdot kg^{-1} \cdot min^{-1}$, joule, metabolic equivalent (MET)] (Ainsworth et al. 2000, International Organization for Standardization 2004). Relative intensity is related to an individual´s capacity (VO_2 reserve, ratings of perceived exertion). Purpose is classified according to the context, such as leisure-time, occupational or commuting activities.

Exercise has been considered a part of PA. Caspersen et al. (1985) describes exercise as planned, structured, and repetitive and purposive in order to improve or maintain one or more physical fitness components. Currently the meaning of exercise is more clearly understood to be that occurring during leisure time and also intended to improve or maintain physical performance or functioning.

2.3.2 Perspectives of leisure time physical activity and exercise in motor abilities

Regular PA, such as walking, cycling, or even dancing, has significant benefits for health. The evidence is conclusive that moderate PA for at least 2.5 hours a week is enough to reduce the risk of cardiovascular disease, diabetes and osteoporosis, help control weight, and promote psychological well-being (U.S. Department of Health and Human Services 2008, Warburton et al. 2010).

Studies concerning the associations between long-term LTPA or exercise and motor abilities or motor performance are almost non-existent. The main interest in follow-up studies has been in morbidity, mortality or health-related fitness (Bijnen et al. 1996, Beunen et al. 1997, Twisk et al. 2000, Baquet et al. 2006, Mikkelson et al. 2006, Paterson et al. 2007). Some longitudinal studies have focused on how LTPA is tracking physical fitness across the lifespan (Glenmark et al. 1994, Malina 1996, Kemper et al. 2001, Tammelin 2005, Mikkelson et al. 2006). Only few studies have been conducted to investigate the associations between LTPA or exercise and motor abilities or motor performance. The association between LTPA and mostly physical fitness, including only a few components of motor performance, has been monitored from school age up to 30 years to detect the effects of maturation (Lefevre et al. 1990, Beunen et al. 1997). So far, only Reed and Metzker (2004) have explicitly studied relationships between overall PA in terms of number of daily steps and several motor abilities and skills (balance, agility and coordination of ball handling). This study was conducted in school-aged children, and the main finding of the study was that the amount of PA was only moderately related to the results of motor tests. It was concluded that the light physical activities of everyday life may not produce enough training effect on motor skills even in childhood.

However, the associations between different modes of LTPA, intensity and a single motor ability, i.e. balance, were studied in a cross-sectional study of adult population (Lindström et al. 2009). According to the results, brisk neuromuscular type of exercising and aerobic exercises were most strongly associated with more stable static and dynamic balance. These findings are in line with the studies among elderly subjects (Voorrips et al. 1993, van Heuvelen et al. 1998). Motor abilities and performance are often considered synonymous with functioning. A 28-year follow-up study of a cohort of white and blue-collar employees showed that vigorous LTPA was associated with reduced risk of low functioning (Leino-Arjas et al. 2004).

Although the knowledge of the associations LTPA and motor abilities among adults is very modest, exercise programmes for motor performance has been recommended and at least older adults should challenge their postural balance and mobility (Paterson et al. 2007, U.S. Department of Health and Human Services 2008). Recently some neuromuscular training programmes designed to enhance motor skills and body control have been carried out. The results of exercising were beneficial in physical functioning among a group of elderly women (Karinkanta et al. 2007). Similar results were found in a study in female floor ball players in order to reduce sport injury risk and improve motor performance (Pasanen et al. 2008, Pasanen et al. 2009).

3 PURPOSE OF THE STUDY

There is a lack of knowledge about the motor abilities of middle-aged population. The data on determinants of motor abilities is limited with respect to exercise and LTPA. Motor abilities have been interpreted in terms of the information processing model of human performance, and the central nervous system is known to regulate motor performance. Therefore, motor abilities may be impaired in several ways due to brain injury. Although problems in motor performance and gross motor clumsiness may be observed clinically after a good recovery, it is not clear how to assess motor performance in rehabilitation.

The general aims of this study are to develop a practical test battery in order to evaluate motor abilities among middle-aged men and women, and to find out if leisure time physical activities and specific exercising contribute to motor performance. As a clinical application, motor performance of men with mild or moderate TBI is examined. The specific aims of this dissertation were (Roman numerals refer to the original publications):

1. To evaluate the test-retest and inter-rater consistency of selected tests for the following basic motor abilities: postural balance, orientation, sense of rhythm, kinaesthetic precision and flexibility (I, II).

2. To ascertain if the motor ability tests can detect the motor problems of physically well-recovered men with TBI, and compare their motor performance with that of healthy men (III).

3. To generate a systematic evaluation of the motor abilities and physical performance capacity as determinants in various exercise modes commonly practised by middle-aged adults. (IV)

4. To investigate the differences in motor abilities and in certain physical fitness components between adults who are physically active or inactive in their leisure time and to examine the association of different modes of exercise and former and recent LTPA with components of motor abilities and physical fitness (V).

4 MATERIAL AND METHODS

This doctoral dissertation consists of four cross-sectional studies and of one theoretical analysis. The Ethical Committee of the UKK Institute, Tampere, Finland approved the study designs of cross-sectional studies on healthy middle-aged population. The studies of a group with traumatic brain injury were conducted with the collaboration of Käpylä Rehabilitation Centre, and the Ethics Committee for Ophthalmology, Otorhinolaryngology, Neurology and Neurosurgery in the Hospital District of Helsinki and Uusimaa, Finland approved the study. All the subjects in each study gave their written informed consent before participation.

4.1 Construction of the test battery to measure motor abilities

A test battery to measure fundamental motor abilities and basic physical fitness components (e.g. aerobic capacity, muscle strength, flexibility) was composed on the basis of an extensive literature search. This included both theoretical background on the classification for motor abilities and the studies of existing tests (Rinne 1996). Some of the selected tests were originally aimed only at school-aged children and these tests were modified to be more appropriate for middle-aged people. The functioning and feasibility of the selected test battery was piloted among adult population and analysed by the author before being used for study purposes (unpublished data). The selected tests to assess motor abilities are presented in Table 3, and the description and detailed instructions are given in Appendix 2.

The order of the tests is described separately under the subheadings of measurements and data collection with respect to each study. The postural balance tests were without exeption conducted first. The reason for this is that concentration, attention, and muscle functions are at their best at the beginning of the test session, and are essential to maintain postural balance. The other motor performance tests followed immediately after the postural balance tests and furthermore constituted a standardized warm-up for the physical fitness tests.

TABLE 3 Description of selected test items for components of motor ability and physical fitness measured.

Components	Test	Measures
Motor abilities		
Kinaesthetic differentiation		
Eye-hand coordination	Vertical ball throw and catch	Points, 0 to 10
Standing broad jump	Standing broad jump	Points, 0 to 3
Spatial orientation		
Explosive strength	Vertical countermovement jump	Height of jump, cm
Ball handling	Bouncing against the wall	Time of 20 throws, s
Reaction ability		
Agility	Figure-of-eight run	Time, s
Rhythm coordination	Marching and clapping at slow pace	Points, 0 to 8
	Marching and clapping at fast pace	Points, 0 to 8
Postural balance		
- Static	Standing on one leg	Time, max. 60 s
	Standing on a narrow bar	Corrective touch, n
- Dynamic	Tandem walking forwards 6 m	Time, s
	Tandem walking backwards 6 m	Time, s
Physical fitness		
Flexibility	Shoulders	Points, 0 to 4
	Forward bending	Fingertip–floor distance, cm
Musculoskeletal strength	Static back muscle endurance	Time, max. 240 s
	Step squat with increasing weights	Points, 0 to 12
Aerobic endurance	2-km walk test	VO_{2max} (assessed)

4.1.1 Test-retest repeatability, reproducibility and feasibility (Studies I and II)

4.1.1.1 Study design and participants

The consistency of the motor performance tests was examined in two separate studies. In the first study (I) consistency was examined in a cross-sectional design which consisted of pretest, test and retest sessions (Figure 3). The sessions were conducted with a 1-week interval. The participants (N=35) without former motor training were recruited from groups on a guided physical activity programme. The inclusion criterion was the participants' statement that their current health and functional status did not prevent participation in LTPA. In total, 25 participants volunteered for the measurements and they all met the inclusion criterion.

In the second study (II) the repeatability was confirmed among TBI patients in order to develop the test battery for clinical use and the reproducibility among a sample of healthy men (Figure 3). In that study the interval between the test sessions was no more than 48 hours. The participants with TBI were drawn from male patients who consecutively entered the Käpylä Rehabilitation Centre over a period of one year. A total of 41 men with TBI were interviewed to ensure eligibility for the study.

The inclusion criteria for the participants with TBI were that they had a diagnosis of TBI and that more than a year had elapsed since the injury. Furthermore, the inclusion criteria for all the subjects were: age 19-55 years, body mass index (BMI) less than 35, passed Mini Mental State Examination (normal > 24/30) that assesses cognitive status in adults, were able to maintain initial test positions, to perform a 2 km Walk Test, and to run a short distance. In addition, a sample of healthy men (N=36) with similar age and educational background distributions to the participants with TBI were invited to participate to serve as a reference for test performance.

Of the patients with TBI, two refused to participate and five were excluded due to the inclusion criteria. In total, 34 men with TBI and all the recruited 36 healthy controls met the inclusion criteria.

The designs of the both studies are presented in Figure 3. The characteristics of the participants in both of these studies are shown detailed in Appendix 1.

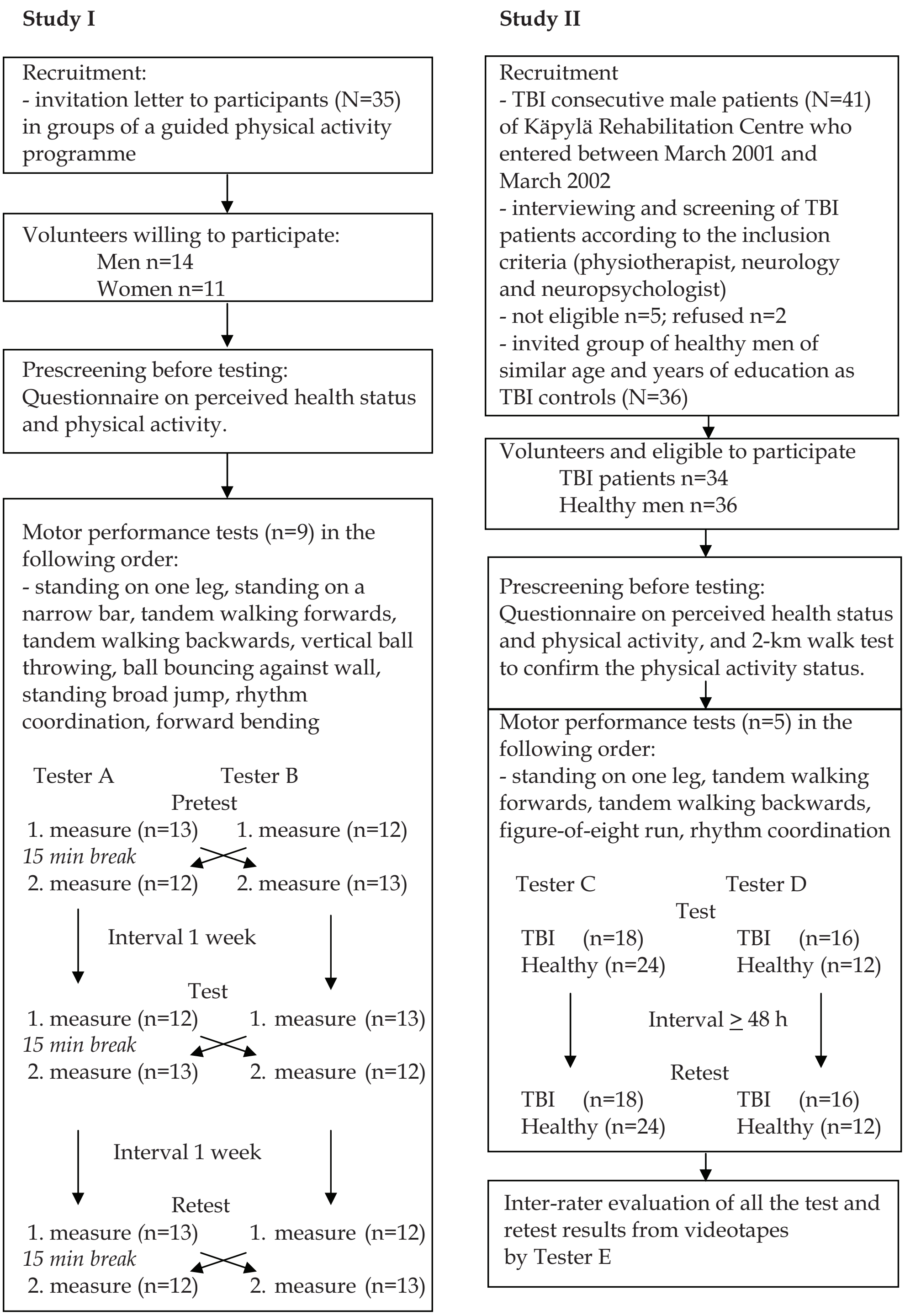


FIGURE 3 Design of consistency studies, protocol and number of participants tested by each tester.

4.1.1.2 Measures and data collection

The consistency of ten tests measuring motor abilities was examined in Study I. The order of the studied tests was: standing on one leg, standing on a narrow bar, tandem walking forwards, tandem walking backwards, vertical ball throwing, ball bouncing against wall, standing broad jump, rhythm coordination test, and flexibility of spine in forward bending. The tests are described more detail in Appendix 2.

Two physiotherapists (A and B) collected the data. They were trained to perform the tests in the same way, and measured the participants independently. Before testing the participants´ health was screened according to the safety model of the UKK Health-Related Fitness Test Battery for Adults (Suni et al. 1996). All participants were tested twice during each of the three test sessions. The starting order of the testers was varied to assess inter-rater repeatability and reproducibility, but the participants performed the tests in the same order in both sessions. The testers gave participants instructions every time concerning each test and the participants had an opportunity to practise briefly before starting the test. The test equipment and conditions were identical in every test situation.

In (Study II) the data was collected by 2 experienced physiotherapists (C and D) in Käpylä Rehabilitation Centre. The tester was the same for each participant in both the first and the second sessions. The five motor ability tests were performed in the following order: standing, tandem walking forwards, tandem walking backwards, figure-of-eight run, and rhythm coordination test (Appendix 2).

The tests for the men with TBI were conducted during the second and third physiotherapy sessions in the first week of the rehabilitation period. The controls were tested in a similar setting. The order of the tests was the same at each session and all the test sessions were videotaped. To determine inter-tester consistency a third experienced physiotherapist (E), who was not present at the tests sessions, assessed the test performances independently afterwards from the videotapes. This assessment was also conducted to ensure the consistency of the test instructions that the testers gave to the participants.

4.1.2 Sensitivity and specificity of the motor ability tests – special emphasis on the motor performance of men with traumatic brain injury compared to healthy men (Study III)

4.1.2.1 Study design and participants

The third study (III) was a cross-sectional study to find out if the results of the motor ability tests of physically well-recovered men with TBI (n=34) differed from those of a control group of healthy men (n=36). The design and the participants of this study were the same as in Study II presented in Figure 3. The characteristics and background distributions (Appendix 1) were quite similar in both groups, but the performance time in the 2 km walk test was statistically significantly slower ($p<0.05$) in the TBI group.

4.1.2.2 Outcome measures and data collection

The main outcome variables were the tests for standing on one leg for static postural balance, tandem walking forwards and backwards measuring dynamic postural balance, figure-of-eight run in terms of agility, and rhythm coordination with slow and fast pace (Appendix 2). Sensitivity, specificity and valid cut-off values of respective motor performance measures were examined for clinical use.

The tests for the men with TBI were performed in Käpylä Rehabilitation Centre during the second physiotherapy sessions in the first week of the rehabilitation period. The controls were tested in a similar setting. In addition, the participants completed a questionnaire on perceived health and fitness status, a physical activity readiness questionnaire, and provided additional information about current and past physical activity and medication.

4.2 Evaluation of motor abilities in commonly practised exercise modes and potential training effects among adults (Study IV)

4.2.1 Study design

Study IV was a theoretical evaluation and conducted with a nominal group (NG) technique aiming at consensus of an expert group on a given issue. The requirements of the motor ability and physical fitness components in different exercise modes were rated in five phases according to the protocol described by Jones & Hunter (1995) (Figure 4).

This consensus method consists of 2 highly structured rating meetings with the guidance of an expert on a topic, called a facilitator. In this study the facilitator invited experts (2 men, 6 women) to join the NG panel. These 8 experts represented professionals with a university degree (M.Sc. or Ph.D.), research on the topics and long practical experience in the fields of physical education (2 members), coaching, exercise testing and prescription (4 members), and health counseling (2 members). All the invited panelists participated in both sessions.

4.2.2 Data collection

The exercise modes (n=30) and lifestyle PA ranked during the first round were based on the PA diaries of middle-aged men and women (n=98). The panellists ranked each component of motor ability and physical fitness for every exercise mode using predetermined scores with respect to requirements of the exercise modes. During the second round the facilitator presented the summary of the first round results to the panellists, and they had an opportunity to consider the exercise modes again and re-rank if necessary.

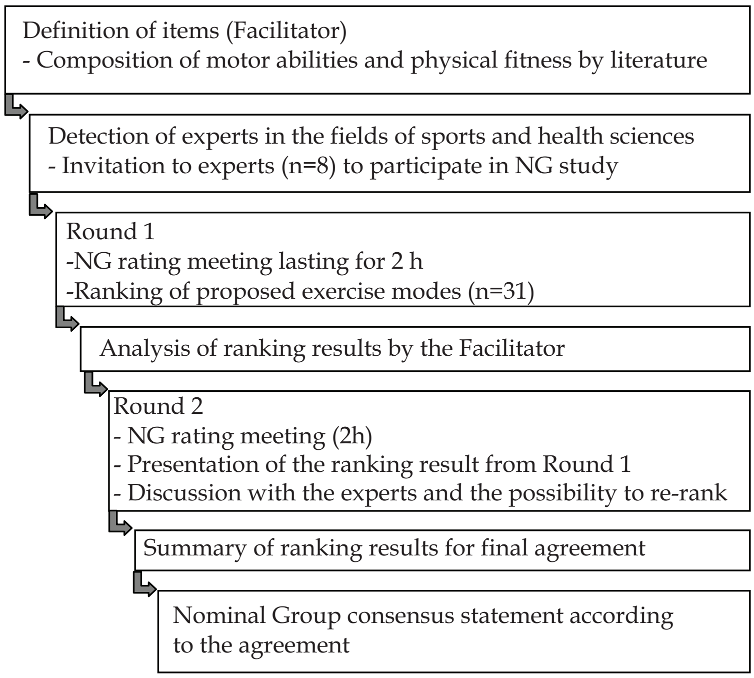


FIGURE 4 Design of Nominal Group Process according to Jones and Hunter (1995).

4.3 Association of different modes of exercise and former and recent LTPA with components of motor abilities and physical fitness (Study V)

4.3.1 Study design and participants

Study V was a cross-sectional study in which the participants aged 41 to 47 years were recruited from an earlier cross-sectional survey conducted to develop measurement scales for Prochaska's stages of change of Health-Enhancing Physical Activity (Miilunpalo et al. 2001). The survey comprised three age groups, and the samples were drawn from census data by stratified random sampling. In the survey, the original sample the age group 41–47 years included 400 men and 400 women representative of the urban, semi-urban, and rural populations in the inland district of Pirkanmaa, Finland. They were invited to participate in this study after the survey reporting had been completed. The respondents reporting activity levels ''hardly any'' or ''some light PA'' (the group of physically inactive) or ''brisk PA about twice a week or more'' (the group of physically active) were considered eligible for Study V.

On the basis of criteria of reported physical activity levels, the letter of invitation was sent a total of 266 eligible respondents. Altogether 148 voluntary participants were invited to participate in the measurements. The design is presented in Figure 5, and the description of the participants is given in Appendix 1.

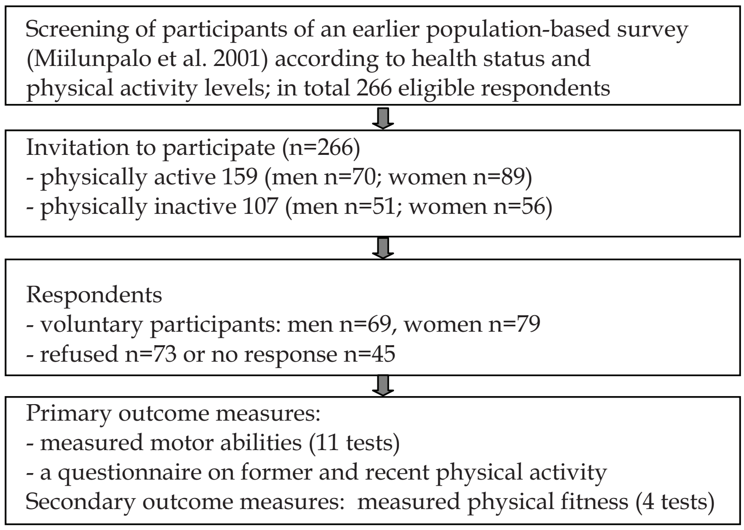


FIGURE 5 Chart of Study V.

4.3.2 Outcome measures and data collection

Participants completed a questionnaire, which was a modified version of the Physical Activity Readiness Questionnaire (MPAR-Q). The questionnaire included questions on perceived health status, frequency, duration and intensity of recent LTPA (R-LTPA) and former LTPA (F-LTPA); i.e., exercise history in terms of years of active exercise, and types and amount of exercise modes. A pretest health screening was done according to the safety model of the UKK Health-Related Fitness Test Battery for Adults (Suni et al 1996) before testing.

The components of motor abilities and physical fitness (Table 3) were assessed with a test battery of 15 selected items (Appendix 2). The test battery was conducted in the following order: standing on one leg, standing on a narrow bar, tandem walking forwards, tandem walking backwards, forward bending of the spine, shoulder–neck mobility, static back muscle endurance test, one-leg step squat test with added weights, rhythm coordination at a slow and fast pace, figure-of-eight run, vertical counter movement jump, vertical ball throwing, ball bouncing, and 2-km walk test.

The data were collected over a period of three-month time. One tester mainly assessed the participants (58 men and 64 women), while another tester with long experience in testing and training motor performance tests assessed 11 men and 15 women.

4.4 Classifications, calculations and statistical analyses

In Studies I, II, III and V (consistency and cross-sectional studies) the descriptive statistics are presented as means, standard deviations (SD) and ranges. The data of the nominal group study was analysed using summary statistics recommended by Jones & Hunter (1995).

4.4.1 Repeatability and reproducibility

To examine test-retest repeatablity and reproducibility of the tests in Studies I and II the analyses used the intraclass correlation coefficient (ICC) for continuous measurements and Cohen´s kappa coefficient (κ) for ordinal and categorical measurements. The ICC's were calculated for single measures by two-way random effects model using absolute agreement definition.

The change in the mean was calculated as the mean differences between 2 trials and describes the systematic (non-random) error. In addition, originally in Study II within-subject standard deviation (also called the standard error of measurement or the typical error) was examined to describe the random change between the repeated measurements (Hopkins 2000, Armitage et al. 2002). The typical error describes the variation in a subject's value from measurement to measurement. Furthermore, the CVs were calculated to ascertain the consistency of tests. Besides the statistics in the original article, the data of Study I was reanalysed to obtain the corresponding typical error. The tests in both of the consistency studies were also completed with the CV calculations and these values are included in the results of this dissertation. Of the statistics, the analysis of variance (ANOVA) with repeated measurements was used to assess the systematic error between the test sessions and between the raters. The systematic error between tests is given as mean difference with 95 % confidence interval (CI).

The following interpretation was used for ICC values: >0.90 = excellent reliability, 0.80 to 0.89 = high reliability, 0.70 to 0.79 = fair reliability, and <0.70 = low reliability (Atkinson & Nevill). Cohen´s kappa coefficient (κ) values was rated as follows: 0.81 to 1.00 = excellent, 0.61 to 0.80 = high, 0.41 to 0.60 = moderate, 0.21 to 0.40 = fair and ≤0.20 = low (Haley & Osberg 1989).

The Bland and Altman plots with 95% limits of agreement were used for a rough indication of the systematic and random error and heteroskedasticity of the data. They show the individual test-retest differences against the mean values of repeated tests (Hulley et al. 2000, Armitage et al. 2002).

In Study I the categorized variables were recoded into two classes for statistical analyses. The points (0 to 4) of the shoulder-neck flexibility test were classified according to the restrictions of the range of movement (ROM):, 0 to 3 points=more or fewer restrictions, and 4 points= no restrictions. The points of the vertical ball throwing and the standing long jump tests were classified according to the accuracy in performance: in vertical ball throwing (0 to 10 points) 0 to 8 points = inaccurate and 9 to 10 = accurate performance; in standing long jump (0 to 3 points) 0 to 2 points=inaccurate and 3= accurate performance). In Study II the data was normally distributed except in the standing on one leg test. Due to skewed distribution of standing times in that test the results were recoded into three categories: low (0-29.9 s), moderate (30-59.9 s) and high (60 s). The points of rhythm coordination test were recoded into 3 categories indicating low (0 to 4 points), moderate (5 to 6 points) and high (7 to 8 points) rhythm coordination.

4.4.2 Cross-sectional studies

In Study III between-group differences of tandem walking tests and agility test adjusted for age were examined by analysis of covariance (ANCOVA). To analyse the group differences of static balance and rhythm coordination tests logistic regression and odds ratios (OR) with their 95% CI were calculated. The results of these tests were used as dichotomous dependent variables, the group variable as independent variable and age as covariate. The rhythm coordination test was a categorized variable and a dichotomous variable was formed according to the accuracy of the test: "synchronous movements" 7 or 8 points, "asynchronous movements" 0 - 6 points.

In order to find the abnormalities in motor performance caused by TBI receiver operating characteristics (ROC) analyses were performed. This evaluates the general performance of the measures and describes the clinical performance of screening tests in terms of diagnostic accuracy. The area under the curve (AUC) in the ROC analyses reflects the probability that a random person with TBI has a higher value of measurement than a random person without TBI. The AUC can take values between 0 and 1 where an AUC of 1 is a perfect screening test and 0.5 represents a test equal to chance. In other words, the larger the surface of the area the better the test discriminates TBI and healthy persons. On the basis of the ROC analyses cut-off values were determined and calculated for all tests with their respective sensitivity and specificity to distinguish "normal" from "abnormal" performance. The perfect cut-off point is in the upper left corner of the graph. For clinical use the point closest to this was considered to be the optimal cut-off value to minimize misclassifications (Hulley et al. 2000, Armitage et al. 2002).

In Study V, the study of middle-aged people, the associations between recent LTPA (R-LTPA) and the test items were described with Spearman's rank correlation coefficients. The R-LTPA was computed as hours of weekly metabolic equivalent (METh·wk^{-1}).The volume (force) of exercises was calculated as MET hours (METh = $\sum_{n=1}^{n} M_i t_i$, where M_i is the MET value for activity, t_i is the duration of activity as hours) (International Organization for Standardization 2004).

Due to skewed distributions, the test variables based on a continuous scale were log-transformed for the analyses. The differences between LTPA groups in the tests were analysed by ANCOVA, where the covariates were age, BMI and occupational physical strain at work. Adjusted geometric mean ratios (GMR) were calculated as antilogs of the differences in group means.

In Study V the data of categorized variables were also recoded for the analyses into dichotomies due to skewed distributions. The standing on one leg test was classified into 2 categories ($\leq$60 s and 60 s), and the points of rhythm coordination test were recoded into 2 categories indicating accuracy of the performance (inaccurate 0 to 6 points; accurate 7 to 8) points. These cut-points for categories were chosen according to the initial distributions of the test results.

The exercise modes (n=30) the participants had gone in for were classified into aerobic, neuromuscular and ball game exercise mode groups. The classification follows the grouping presented by Heyward (2005). Lifestyle physical activity was elicited but not included in this analysis. Table 4 shows in detail the groups of exercise modes, each group in alphabetical order.

TABLE 4 Exercise modes reported in Study V classified into groups according to their most predominant feature.

Aerobic	Neuromuscular	Ball games
Aerobics	Archery	Badminton
Canoeing	Callisthenics	Basket ball
Cross country skiing	Downhill skiing	Bowling
Cycling	Jazz dance	Floorball
Dance	Martial arts	Golf
Orienteering	Weight training	Ice hockey
Roller skating		Squash
Rowing		Table tennis
Running/Jogging		Tennis
Swimming		Volleyball
Skating		
Track and field		
Walking		

The differences between LTPA groups were analysed in tests with categorical scale by Pearson's χ^2 -test. Furthermore, stepwise linear regression analysis was used to assess the multiple associations with the continuous test variables of the components of motor abilities and physical fitness. The possible confounding variables (age, BMI and occupational physical strain) were included in all analyses. Logistic regression analysis was used in analysing the between-group differences of categorized test variables.

In all studies the alpha value of 0.05 was used in all analyses as the level of statistical significance.

4.4.3 Nominal group study

The mean, median and mode were calculated for each of the motor abilities with the respective exercise mode ranked in the first NG round. At least one value of the ranked abilities ought to be $\geq$ 2 round to be included in further consideration in the second NG round. The totals of points given for each ability included (maximum 24 points) were calculated and built into the final statement. In addition, all the given points of five motor abilities and physical fitness for each exercise mode were summed (maximum 120 points) to indicate total requirements.

5 RESULTS

The characteristics of all the participants in each study are presented in Appendix 1. The geometric means with corresponding minimum and maximum values for this motor performance and physical fitness tests examined in Studies I, II, III and V (consistency and cross-sectional studies) are presented in Appendix 2.

5.1 Consistency of the tests measuring motor abilities (Studies I and II)

In total, the consistency of ten tests was tested separately in the Study I and Study II. The tandem walking forwards and backwards, standing on one leg and rhythm coordination tests were conducted in both studies.

The results of repeatability in terms of change in the mean, typical error and CV are summarized in Table 5. The typical errors and CV for the continuous test variables from both studies were within acceptable limits almost in all the tests. However, the typical error seemed to be greater in every respect among the group of men with TBI than among their healthy controls.

CV showed high repeatability in Study I in the tests of tandem walking forwards and backwards, and rhythm coordination test. In Study II the repeatability was excellent in the figure-of-eight run for both study groups (Table 5).

In Study I the test-retest results of tandem walking backwards walking did not differ statistically significantly. In Study II the ICC values of both tandem walking tests showed high test-retest repeatability among TBI group, but among the healthy men it was only fair and in tandem forwards walk low. In both studies the participants improved the performance times of the tandem walking tests between the sessions, which indicates some training effect. In Study II the range of individual test-retest difference was greater in the TBI group. However, in the Bland-Altman plot the individual test-retest differences were within the 95% limits of agreement regardless of the performance time.

In the rhythm coordination test most of the participants achieved high scores (12 -16) in Study I. Accordingly, no large individual test-retest differences were found in the Bland-Altman plot. In Study II the results of rhythm coordination test were examined in more detail. With slow rhythm about 60 % of subjects in the TBI group and nearly 90 % in the control group performed the rhythm coordination accurately in both sessions (κ=0.58 and 0.26 respectively). In the fast rhythm phase the results improved between the sessions and in the TBI group the proportion of those with a accurate performance was 38% in the first session and 53% in the second (κ=0.52). In the control group the proportions were 78% and 92% respectively (κ=0.40).

The consistency of figure-of-eight run was studied only in Study II. The retest performance times improved more in the TBI group than in the control group (Table 5). However, the ICC values indicated high repeatability in figure-of-eight run in both groups (Table 5). Individual test-retest differences showed wider variation between trials among the TBI group than among the control group.

In Study I repeatability was high in the ball bouncing test according to ICC value even though the bouncing time was shorter in the retest than in the test session and CV showed only reasonable repeatability (15%) (Table 5). In the Bland-Altman plot the 95% limits of agreement were affected by a few outliers but they had no effect on repeatability. Furthermore, the test-retest differences did not depend on the length of bouncing time.

Standing on one leg, flexibility and vertical ball throwing were excluded from further statistical analyses in Study I due to the lack of variation between the participants. The results indicate that the participants in Study I could perform these tests without difficulty. In Study II the standing on one leg test was studied for both legs and slightly over 50% of the men with TBI succeeded in reaching the maximum 60 seconds on both legs. This apparently differed from the results of the control group where about 90 % of the participants reached the maximum. However, further analyses showed that the repeatability with respect to the change in the mean and CV was high among the participants in Study I and among the healthy men in Study II.

Only two of the ten tests studied showed very low consistency. The standing broad jump test results were scored as a categorical variable, and 13 of the 25 participants got exactly the same result in all the sessions, and the kappa coefficient was only fair (κ=0.32). In the test of standing on a narrow bar the ICC value was fair but the training effect was found between sessions as the number of supportive touches the decreased in the retest session and the difference between test-retest was statistically significant.

TABLE 5 Results of consistency (repeatability) measures examined in terms of motor ability components and tests with continuous test variables. ("TBI" refers to men with traumatic brain injury and "C" to their controls.)

Motor abilities	**Change in the mean**			**Typical error**			**CV (%)**☼			**ICC** ♦		
	Study 1	Study 2		Study 1	Study 2		Study 1	Study 2		Study 1	Study 2	
		TBI	C		TBI	C		TBI	C		TBI	C
Static postural balance												
Standing on one leg	1.9	-1.7	-0.7	4.6	9.3	6.4	8	20	11	¥		
Standing on a bar (corrective touches; n)	-1.0			1.1			26			0.92		
Dynamic postural balance												
Tandem walking forwards 6 m (s)	-0.3	-1.2	-1.7	0.5	1.7	1.1	4	11	10	0.91	0.84	0.68
Tandem walking backwards 6 m (s)	-0.2	-1.8	-2.2	1.0	2.0	1.6	8	13	12	0.85	0.80	0.71
Agility/ Explosive muscle strength												
Figure-of-eight run (s)		-0.3	-0.2		0.3	0.1		3	2	0.83	0.97	0.87
Ball handling skills												
Bouncing against wall (s)	-1.6			3.8	1.2	1.3	15	11	9	0.70		
Rhythm coordination												
Slow and fast phases combined (points)	0.2	-1.2	0.8	0.9			5					
Flexibility												
(finger-tip to floor; cm)	-0.1			0.9			20			¥		

☼ CV, coefficient of variation. ♦ ICC, intra-class correlation coefficient, ¥ Excluded from ICC analyses due to the lack of variation between participants.

In Study I the inter-rater assessment was examined between two testers. No systematic error between raters was found in both types of tandem walking tests and ball bouncing test, and the inter-rater ICC values were high to excellent. In the rhythm coordination test the inter-rater ICC value was fair. However, on the postural balance test on a narrow bar the inter-rater evaluation differed statistically significantly ($p<.001$) between raters. In addition, an obvious systematic error between the raters was found.

Inter-rater repeatability was also determined in Study II between the measurements of the initial testers and the measurements evaluated from videotapes. In the standing on one leg test there were no differences. The inter-rater differences in tandem walking forwards and backwards, and figure-of-eight run were also insignificant. In the assessment of rhythm coordination the inter-rater repeatability was high with the slow rhythm both in the first and second sessions and in the TBI and control groups. High agreement was also found in the fast rhythm in the first session but only moderate in the second due to the smaller variation in the results of the last session.

5.2 Comparison of motor performance of physically well-recovered men with traumatic brain injury with healthy men (Study III)

The participants of Study III were the same as that in Study II, described in Appendix 1. Overall, 79% (24 men) of the TBI group reported that they had had to change their sports activities after injury and 4 men in the TBI group had totally abandoned their former sport activities.

According to the logistic regression analysis the TBI group had statistically significantly lower static postural balance than the controls. Nearly half of the TBI group were unable to maintain their postural balance on one leg for 60 seconds [44% vs. 14% on the right; 50% vs. 8% on the left leg; ORs 4.6 (95% CI 1.4 to 15.3, $p<.05$); and 10.7 (95% CI 2.7 to 43.6, $p<.001$) respectively]. The TBI group performed tandem walking forwards and backwards statistically significantly more slowly ($p<.001$ and $p<.05$ respectively) than the control group. In the agility test the TBI group running a figure-of-eight was statistically significantly slower than in the control group ($p<.001$). In the slow rhythm coordination 41% of the subjects in the TBI group had difficulties in starting or/and maintaining the given rhythm, but only 14% in control group performed the test inaccurately [OR 4.3 (95% CI 1.3 to 13.9), $p<.05$]. At fast rhythm 62% of the men in the TBI group performed the rhythm coordination test asynchronously, whereas only 22% of the controls provided an asynchronous performance [OR 8.5 (95% CI 2.6 to 28.3), $p<.001$].

Sensitivity, specificity and optimal cut-off points for each test are given in Table 6 and the ROC curves are presented in Figure 6. The probability of detecting problems in motor performance caused by TBI was best in the figure-of-eight run. Of dynamic postural balance tests the tandem walking forwards and the test for fast rhythm had also high sensitivity and specificity.

TABLE 6 Area under curve (AUC) in the receiver operating characteristic (ROC) reflects the probability that a random person with TBI has a higher value than a random person without TBI. The optimal cut-off point for each test is based on their respective sensitivity and specificity to identify the men with TBI from healthy subjects. (Sensitivity: true positive rate. Specificity: 1-false positive rate.) (Rinne et al. 2006)

Test	**AUC (95% CI)**	**Cut-off point**	**Sensitivity (%)**	**Specificity (%)**
Tandem walking forwards	0.76 (0.65-0.88)	≥13.0 s	70.6	77.8
Tandem walking backwards	0.70 (0.57-0.82)	≥16.0 s	55.9	77.8
Running figure-of-eight	0.86 (0.78-0.95)	≥7.2 s	73.5	86.1
Standing on one leg (max. 60s)				
On the right leg	0.65 (0.52-0.78)	≤59 s	44.1	86.1
On the left leg	0.71 (0.59-0.84)	≤55 s	50.0	91.7
Rhythm coordination				
Slow rhythm (max. 8 points)	0.70 (0.57-0.82)	≤7 points	64.7	69.4
Fast rhythm (max. 8 points)	0.75 (0.63-0.86)	≤6 points	61.8	77.8

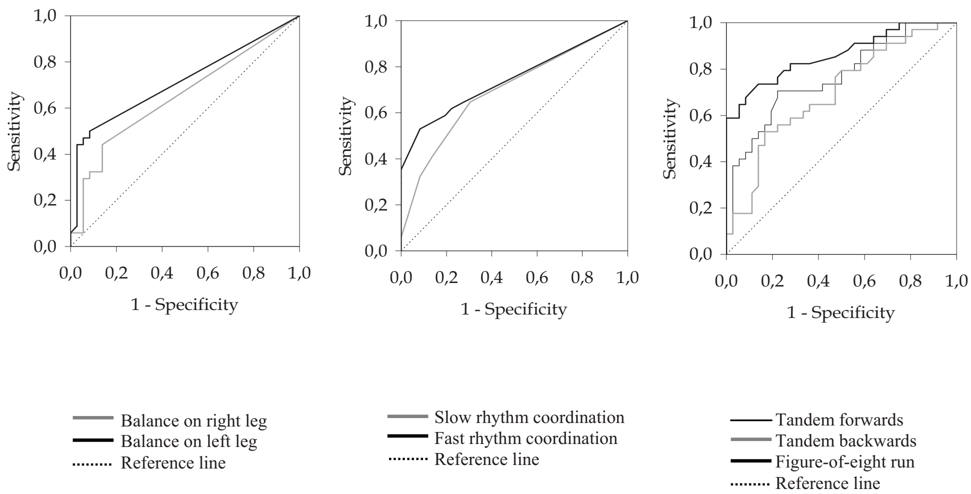


FIGURE 6 In the ROC curve diagrams a 45° line shows an AUC of 0.5. The cut-off point closest to the upper left corner of the graph is the optimal cut-off value to minimize misclassifications (Rinne et al. 2006).

5.3 Systematic evaluation of the motor abilities and physical performance capacity in various exercise modes practiced by middle-aged adults (Study IV)

The final statement of rankings of the motor abilities in different exercise modes is given in Table 7. The NG group panellists estimated that roller skating, downhill skiing and martial arts are the most demanding exercise mode requiring all five determinants of motor abilities when a novice starts to exercise (Table 7). Four motor abilities were ranked in skating, jazz dance and ice hockey. In eight exercise modes at least three motor abilities were required: cross country skiing, dance, badminton, table tennis, squash, floor ball and volleyball but only two of five motor abilities were ranked in aerobics, bowling, golf, basketball, track and field, archery, swimming, cycling, canoeing and weight training (Table 7).

Of the components of motor abilities the panellists considered that the kinaesthetic differentiation was the most common ability with regard to exercise modes ranked in NG. Both orientation and postural balance were considered nearly in half of the modes. As a consequence, the panellists considered that kinaesthetic differentiation was combined with spatial orientation in all 12, and with postural balance in 10 exercise modes. However, these three abilities were present concurrently in only five exercise modes. These were roller skating, downhill skiing, martial arts, jazz dance and ice hockey. Moreover, the reaction ability was in conjunction with kinaesthetic differentiation in 12 exercise modes, especially racket games, in which the postural balance was within this combination. Rhythm coordination was considered important in all exercise modes with music, and furthermore in skating, roller skating and downhill skiing. In the second round the panellists voted for the rhythm coordination to be added as one of the motor ability determinants in bowling and basketball. (Table 7)

Concerning the target-oriented training the NG panelists ranked most of the exercise modes to have a remarkable training effect on motor abilities. Overall, 14 exercise modes (45%) were considered to have a training effect in order to improve all five motor abilities and six exercise modes (19%) to improve at least four abilities. Running/jogging, walking and rowing were the only exercise modes which the panellists considered not to have remarkable training effects on motor abilities compared with the other modes.

Regarding the components of physical fitness the NG panellists agreed that most of the exercise modes (27) contribute to endurance capacity when exercising is target-oriented. On the whole, 22 out of 30 ranked exercise modes had a training effect on muscle strength. The panellists also found all the ball games to promote agility and endurance training. Although most of the exercise modes have positive effects on physical fitness the components of motor abilities are trained even more.

TABLE 7 The exercise modes are grouped according to the final ranking of the the nominal group. The grey colour indicates the motor ability determinants (0 to 5) needed. The most demanding exercise modes are those with 5 motor abilities. The sums of the total points given are presented.

Exercise mode	**Spatial orientation**	**Kinaesthetic differentiation**	**Reaction ability**	**Rhythm coordination**	**Postural balance**	**Total sum** (max.120)	
Rollerskating	■	■	■	■	■	80	**5 abilities**
Downhill skiing	■	■	■	■	■	75	
Martial arts	■	■	■	■	■	66	
Jazz dance	■	■		■	■	65	**4 abilities**
Skating		■	■	■	■	63	
Ice hockey	■	■	■		■	57	
Cross country skiing	■	■		■		41	**3 abilities**
Dance	■		■	■		45	
Badminton		■	■		■	41	
Table tennis		■	■		■	44	
Tennis		■	■		■	44	
Squash		■	■		■	44	
Floorball	■	■	■			39	
Volleyball	■	■	■			47	
Aerobics	■			■		30	**2 abilities**
Bowling				■	■	23	
Golf	■	■				28	
Basketball		■		■		24	
Track and field	■	■				35	
Archery	■	■				29	
Cycling					■	17	**1 ability**
Swimming				■		11	
Weight training		■				14	
Canoeing					■	13	
Walking, running, jogging, rowing, orienteering, calisthenics, and life style PA							**None**

To give a general view of the diversity and the entity of different requirements and training effects a summary of motor abilities and physical fitness of exercise modes is presented in Figure 7.

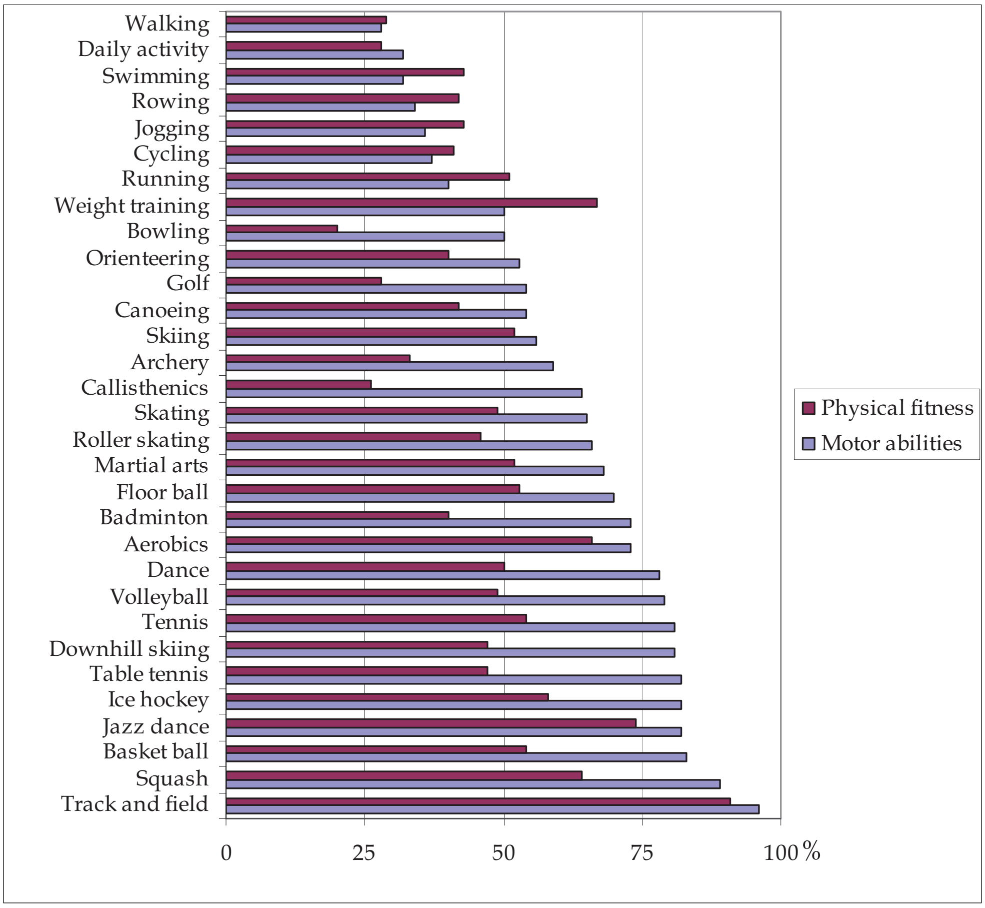


FIGURE 7 The histogram shows the rated training effects on components of motor ability and physical fitness of evaluated exercise modes as the percentage of maximum points (120 points/component).

5.4 Associations between LTPA and motor abilities and some components of physical fitness (Study V)

In Study V the association of motor abilities and some components of health-related fitness with recent and former LTPA were examined to ascertain whether the results for physically active and sedentary adults differed in terms of exercise types. Multiple statistical analyses were used in order to answer different questions. Due to statistically significant differences between the test results of men and women the group analyses were conducted separately for both genders and are reported accordingly.

Spearman´s rank correlation coefficients were examined to find out if the R-LTPA in terms of $METh \cdot wk^{-1}$ [the volume (force) of exercises calculated] is associated with the test results. In this analysis the participants were not split into groups according to physical activity. In the associations between the single test items and R-LTPA, the trend was that higher $METh \cdot wk^{-1}$ correlated with better test results with continuous variables (Table 8).

TABLE 8 Associations between the single test items and R-LTPA in terms of $METh \cdot wk^{-1}$ and their corresponding Spearman's rank correlation coefficients (R_S).

Test item	All (N=148) R_S	Men (n=69) R_S	Women(n=79) R_S
Postural balance on a bar	-.18*	-.25 *	.41 *
Tandem walking forwards 6m	-.21*	-.19	-.19
Tandem walking backwards 6m	-.17*	-.19	-.14
Ball bouncing against wall 20 times	-.12	-.20	-.03
Figure-of-eight run	-.17*	-.28*	-.17
Fingertip–floor (flexibility)	-.11	-.15	-.06
Vertical jump	.06	.10	.11
Step squat	.17*	.02	.36 *
Static back endurance	.16*	.07	.25 *
2-km walk test (VO_{2max})	.23*	.22	.36 *

* p value <.05

However, in the tests with categorized test results (rhythm coordination, vertical ball throwing or shoulder flexibility tests) $METh \cdot wk^{-1}$ was not associated with any of the test variables.

First, the differences between physically active and inactive groups, each test was analysed by ANCOVA and Pearson's χ^2 test (with age, BMI and occupational physical strain at work as the covariates). Table 9 shows adjusted geometric mean ratios according to recent training intensity, years of LTPA and exercise modes and the between-group differences (ANCOVA). In the individual analyses men who reported playing several (two or more) ball games had statistically significantly better results in five out of eight tests: postural balance on a narrow bar, tandem walking backwards, bouncing the ball against the wall, in the vertical jump and the figure-of-eight tests. The F-LTPA was also statistically significantly associated with the figure-of-eight test. In women between-group differences were found in several individual tests (Table 9). However, endurance training was the only variable in which no statistically significant differences between physically active and inactive women were found in any test.

According to the results of ANCOVA or χ^2 test the variables that showed statistically significant differences ($p < 0.05$) were included in the further regression analyses. When the LTPA variables were included as predictors in stepwise regression analyses, only one variable, playing two or more ball games was a statistically significant predictor for the same tests as in individual analyses for men.

In stepwise regression analyses conducted among women the duration of LTPA and playing ball games remained statistically significant predictors for tandem walking forwards. For tandem walking backwards the strongest predictors were the duration of LTPA and intensity of exercising. In the figure-of eight run a between-group difference found in duration of LTPA was also the only statistically significant predictor in stepwise regression (Table 9). Similarly the same variable was found to be the strongest predictor in the regression analysis for the tests of static back muscle endurance and cardio-respiratory fitness (VO_{2max}) while neuromuscular training was the only statistically significant predictor for vertical jump (Table 9).

Vigorous R-LTPA was the only statistically significant predictor in the logistic regression model for a high result in the standing on one leg test. In total, 73% of women with vigorous R-LTPA succeeded in gaining the maximum time in postural balance on one leg, whereas 23% of the women with light intensity R-LTPA reached the maximum. In the step squat test the maximum result was reached by 83% of women whose training intensity had been vigorous (vs. 17% for women with light intensity; $p<.001$), 60% of those with over 3 years of LTPA (vs. 40% of women with less LTPA; $p<.05$), and 74% of women with neuromuscular training (vs. 26% of women with no neuromuscular training; $p<.001$). However, when all the individual items were entered into a stepwise logistic regression analysis at the same time, the strongest predictor for the maximum result was duration of LTPA.

In respect of intensity, duration or modes of LTPA, no differences between physically active and inactive participants were found in the test results for shoulder flexibility, rhythm coordination or vertical ball throwing.

TABLE 9 Differences in motor and physical performance tests between active and inactive participants according to recent intensity of exercising, exercise history in years and different modes of leisure time physical activity (LTPA). The results are given as geometric mean ratios (GMRs) with 95% CI.

Men	Recent LTPA intensity light vs. vigorous (n=26/43)	Duration of LTPA < 3 vs. ≥ 3 years (n=21/48)	Endurance training none or 1 vs. ≥ 2 (n = 33/36)	Neuromuscular training none vs. ≥1 (n = 49/20)	Ball games none or 1 vs. ≥ 2 (n = 48/21)
Postural balance on a bar (touches)	1.19 (0.78–1.80) †	1.43 (0.93–2.20)	1.11 (0.73–1.69)	0.83 (0.55–1.28)	1.53 (1.01–2.32)* ¶
Tandem walking forwards (s)	1.04 (0.90–1.20)	1.10 (0.95–1.28)	1.04 (0.90–1.20)	1.14 (0.98–1.32)	1.12 (0.96–1.29)
Tandem walking backward(s)	1.03 (0.91–1.17)	1.07 (0.94–1.23)	0.99 (0.87–1.13)	1.11 (0.98–1.26)	1.16 (1.02–1.31)*¶
Ball bouncing (s)	1.01 (0.91–1.11)	1 .10 (1.00–1.21)	0.99 (0.90–1.09)	1.00 (0.90–1.10)	1.16 (1.06–1.27)* ¶
Jump height (cm)	0.98 (0.89–1.08)	0.91(0.83–1.00)	0.99 (0.90–1.10)	0.99 (0.90–1.10)	0.91 (0.82–1.00)* ¶
Figure-of-eight run (s)	1.03 (0.96–1.10)	1.08 (1.01–1.16)*	0.98 (0.92–1.05)	0.98 (0.92–1.05)	1.09 (1.02–1.16)* ¶

(continues)

(Table 9 continues)

Women	Recent LTPA intensity light vs. vigorous (n=29/50)	Duration of LTPA < 3 vs. ≥ 3 years (n=45/34)	Endurance training none or 1 vs. ≥ 2 (n=38/41)	Neuromuscular training none vs. ≥1 (n=37/42)	Ball games none vs. ≥ 1 (n=64/15)
Postural balance on a bar (touches)	1.01 (0.75–1.36)	1.52 (1.16–2.01)*	1.17 (0.88–1.56)	1.13 (0.85–1.50)	1.03 (0.71–1.50)
Tandem walking forwards (s)	1.12 (1.00–1.26)	1.18 (1.06–1.32)* ¶	1.09 (0.97–1.22)	1.04 (0.91–1.14)	1.23 (1.07–1.42)* ¶
Tandem walking backward(s)	1.15 (1.01–1.30)* ¶	1.16 (1.03–1.32)* ¶	1.11 (0.98–1.26)	0.98 (0.86–1.11)	1.10 (0.93–1.30)
Ball bouncing (s)	1.05 (0.94–1.17)	1.05 (0.94–1.17)	1.04 (0.94–1.16)	0.93 (0.84–1.03)	1.13 (0.98–1.30)
Jump height (cm)	0.96 (0.89–1.04)	0.91 (0.85–0.98)*	0.99 (0.92–1.07)	0.91 (0.85–0.98)* ¶	0.99 (0.90–1.08)
Figure-of-eight run (s)	1.02 (0.98–1.06)	1.04 (1.01–1.08)* ¶	1.02 (0.98–1.06)	1.01 (0.97–1.05)	1.03 (0.98–1.08)

† Geometric mean ratios (95% CI) between active and inactive groups were estimated by an analysis of covariance and adjusted for confounders (age, BMI and occupational strain at work).
* The adjusted difference between groups is statistically significant at level $p < 0.05$ (ANCOVA).
¶ Statistically significant predictor in stepwise regression analysis.

6 DISCUSSION

6.1 Consistency of the motor performance tests

In Studies I and II the tests were selected on the basis of a systematic literature review in order to measure different components of motor performance and fitness. While the selected motor and physical performance tests have been widely used, studies on their consistency are rare. In this dissertation the main concern in the selected tests was adequate consistency in terms of change in the mean, typical error and ICC.

On the basis of the results of Studies I and II, further calculations were made to express the standard deviation as a percentage of the sample mean in terms of CV, which is useful when comparing the variation between different units. In sports sciences within-subject CV 1% to 5% i.e. in the tests of VO_{2max} has been considered entirely repeatable (Hopkins 2000). However, even a CV range up to 15 % indicates high repeatability (Hopkins 2000). The smallest CV among the tests studied was found in figure-of-eight run. The CVs of standing on one leg, both types of tandem walking, rhythm-coordination and bouncing the ball tests ranged from 5% to 15%, which is still a reasonable variation for the repeatability of tests. This coefficient of variation should be taken into consideration when the tests are used in follow-up or intervention studies, and the training effects are studied.

In an earlier reliability study of a health-related fitness test battery (Suni et al. 1996) reproducibility was measured mostly for components of musculoskeletal fitness. Nelson et al. (1994) used backwards tandem walking as a dynamic postural balance test for elderly women. Repeatability was measured by the correlation coefficient, which seemed to be high ($r=0.94$, $p<0.001$) between repeated measurements one week apart, as also in our results. The repeatability of the ball bouncing test was not assessed in the original study (Verstappen et al. 1997) but in a study of volleyball players with mental retardation the test-retest repeatability for four volleyball subtests was high according to the intraclass correlation coefficient (ICC 0.82-0.90) (Downs & Wood 1996).

In this test battery the homogeneity of the participants in Study I and the healthy men in Study II became restrictive for the analyses, especially in the stand on one leg test. However, in an earlier study among a larger adult population (n=498), the stand on one leg test had acceptable test-retest repeatability, and a moderate amount of variability was reported (Suni et al. 1996). In Study II the variation among men with TBI was greater than among the controls. Consequently, the test was found to be appropriate in a clinical setting and complementary to the Berg Balance Scale, which has been used as a measure of functional ability.

Another important observation in both consistency studies (I and II) was that the systematic improvement in the results of some motor performance tests indicates a motor learning or training effect between sessions. It has been stated that already learned movement skills can be successfully recalled after a few repetitions even though they have not been practised for a long time (Schmidt & Lee 2005). The same was true in two walking test studies in which a real pretest showed it to be essential to familiarize participants with test and increased repeatability (Oja et al. 1991, Laukkanen 1993).

A general observation in Study I was that the repeatability of tests with continuous variables was better than that of tests with categorical variables. Consequently, the crucial unclear points in test instructions were identified and completed before starting Study II. Thus the scoring did not depend on the raters, and the interpretation was more clearly stated. This experience shows that when the instructions are explicit and all the testers are well trained to perform and follow the instructions, reproducibility improves.

The repeatability and reproducibility analyses of Studies I and II showed that most of the motor performance tests studied had high consistency in terms of change in the mean, typical error and ICC. Moreover, they were acceptable and feasible even in a clinical setting to measure the motor performance of men in TBI rehabilitation. Some tests had a ceiling effect and such tests should therefore be used with caution; further research and development of them are needed.

6.2 Motor performance tests for TBI patients in clinical use

It is well established that after TBI even mild changes in the ability to pay attention, process, recall, and act upon information can profoundly affect an individual's motor performance, daily functioning, and cause disability (Consensus Conference 1999, Bateman et al. 2001, McFadyen et al. 2003).

According to Study III, statistically significant differences in the results of motor performance tests between the TBI and control groups were indeed found. The TBI group had difficulties in maintaining static postural balance, controlling dynamic balance, and coordinating simultaneous hand and foot movements in a given rhythm. The time in the agility test was also statistically significantly slower than in the control group. These results therefore corroborated subjectively described experiences. In addition, these results concur with those of other studies reporting postural balance and more complex motor tasks involving coordination are common functional deficits after TBI (Geurts et al. 1996, Azouvi et al. 2004).

The cut-off points with the best sensitivity and specificity for clinical use were determined. The figure-of-eight run, fast rhythm coordination and tandem walking forwards tests were the best for screening out men with TBI from healthy controls. The variations in sensitivity and specificity rates in most of the tests were from 60% to 100% for clinically meaningful cutting scores.

The findings are in line with an earlier study on patients with TBI which reported overall reduced postural control and speed of movements (Ponsdorf et al. 1995, Geurts et al. 1999, Cantin et al. 2007). Traditionally tandem walking has been used as a measure of dynamic postural balance after TBI, but the focus has been on mistakes during its performance. In Study III the walking time turned out to be more revealing than the observation of errors in postural balance. This suggests that in addition to the assessment of postural balance, gait speed may even indicate impairment in cognitive information processing and executive functioning among patients with TBI (Cantin et al. 2007).

Studies have also shown that a substantial portion of young patients with TBI who can walk independently after recovering may be unable to run (Ponsdorf et al. 1995). With respect to the sensitivity and specificity values, the figure-of-eight run test proved to be the best test for screening out men with TBI from healthy controls. In complex environments cognitional executive functioning and attention are associated with locomotor behaviour following TBI (Cantin et al. 2007). This test reveals all these elements.

Many TBI patients who have recovered well and even achieved a high level of motor performance have more difficulties in dual tasks with simultaneous movements of the upper and lower limbs than do their uninjured counterparts (Azouvi et al. 2004, Cantin et al. 2007). In this study TBI patients (41%) had difficulties while simultaneously marching and clapping hands to the given slow rhythm, but the fast rhythm coordination task revealed even more problems (62%). Similarly, Parker et al. (2005) compared healthy subjects and subjects sustaining concussion, and found that both groups had slower walking speed during dual task conditions than in routine walking, but subjects with concussion were more affected.

Although all the men with TBI in this study had recovered well physically, they had described their subjectively perceived motor deficiencies as defects in balance, difficulties in running, clumsiness in arm movements and fatigue. Almost all of them had had to change their sports or physical activities after injury. The results of Study III established deficiencies in motor performance and were in accordance with those descriptions. Furthermore, according to the ROC analyses, the cut-off points determined enable the more precise/accurate assessment of different aspects of motor performance. The test battery used in Study III can be recommended for inclusing in the motor performance assessment of physically well-recovered TBI patients when conventional neurological examinations are not sensitive enough in a clinical setting.

6.3 Contribution of leisure time physical activities and specific exercise to motor abilities

It is well known that the determinants of different exercise modes or their training affect motor performance and physical fitness. However, the parallel examination of different exercise modes in terms of motor performance and physical fitness is rare or has been limited to coaching purposes of elite athletes (Kioumourtzouglou et al. 1998, Thomson et al. 2008). Study IV was conducted to achieve an evaluation of the motor abilities and physical performance capacity as determinants of exercise modes commonly practised by middle-aged adults. Study V examined the associations of different modes of exercise and LTPA with motor abilities and certain physical fitness components, and whether such components of physically active adults are different from those of physically inactive adults.

With respect to the results of Study IV, most motor abilities seemed to be needed in exercise modes requiring speed of movement and performed in varied environment or with equipment, and where the external determinants vary. However, the complexity of exercise modes is difficult to operationalize but many of them consist of processing auditory, visual and tactile information to anticipate and control the neural input in relation to the needed strength, distance and timing. Among motor abilities this refers to kinaesthetic differentiation, which was also found to be most common in the exercise modes evaluated.

Rhythm coordination was another important determinant. Understandably all exercise modes performed to music require a sense of rhythm, but rhythm coordination occurs in skilled performance (Shaffer 1982), and is observed, for instance, even in swimming, bowling and basketball. Given that neurophysiological organs regulate rhythmic movements in terms of basic timing, synchronization and sequencing of performance (Grahn & Brett 2007, Thaut et al. 2008), this suggests that rhythmical movements may be present in more exercise modes than stated in the NG evaluation, and these may be generated either performer-related internally or cued by an external stimulus (Serrien et al. 2007).

Nevertheless, a single motor ability alone is insufficient for successful motor performance, which indicates that combinations and modifications of different motor abilities are needed to control movements in different exercise modes (Hirtz 1985). When training is goal-oriented, specific exercise modes or a single exercise mode may be found effective in developing all motor abilities or physical fitness. Furthermore, the studied exercise modes were also in accordance with Ainsworth´s compendium (2000) in terms of MET values.

In Study V the effects of overall recent LTPA in terms of METh·wk^{-1} on motor abilities were examined first. We found that higher METh·wk^{-1} correlated most strongly with the motor abilities in terms of static postural balance and agility in men, and, as expected, with the fitness with the components of cardiorespiratory and muscle strength in women. When the results of men and women were pooled the higher METh·wk^{-1} indicated a better result in all the tests of physical fitness but also in the postural balance and agility tests. Given that METh is a measure of PA volume and the product of intensity (3, 5 or 7 MET), women who are less physically active may have relatively higher physical load because of the same intensity in METs, e.g. 5 MET means a greater strain on women whose capacity is lower. Alternatively, anthropometric measures also favour men: cardiovascular and respiratory responses are largely a result of differences in body size, body fat partly explains the differences in V02max, and the muscle strength can be explained by the fact that men have larger muscle fibre cross-sectional areas than women due to testosterone-estrogen differences (Wilmore 2005). Nevertheless, the inherent mechanisms of motor control are similar for both genders.

For regression analyses the participants were distributed in relation to the volume of physical activity to represent inactive and active participants. The current recommendations suggest that the range of weekly activity level should be from 450 (minimum) to 750 MET·min·wk^{-1} (Haskell et al. 2007). The lower limit (7.5 METhours per week) is regarded as a cut off-level to derive health benefits and corresponds to 30 minutes of moderate physical activity 5 days per week (Bowles et al. 2004). In Study V almost half of participants remained under the recommended activity level. Between the recommended cut-off points there were 19% of men and 34% of women and they were also classified as physically active participants in addition to those with activity 750 MET·min·wk^{-1} or more.

When the effects of F-LTPA on motor abilities were assessed among the men, the strongest predictor in five out of eight tests was exercise history of playing ball games. This confirms the NG statement where ball games were reached to 70% to 90% of the maximum points with respect to training effects on motor abilities, whereas corresponding effects on physical fitness were rated at 40% at best. This is in line with Heyward (2005) and Wilmore et al. (2008), who also considered ball games to challenge neuromuscular coordination and skills. On the whole, many motor ability characteristics such as speed, agility, changing direction, timing and coordination occur concurrently with playing ball games (Thomson et al. 2008).

Among women in almost all motor performance tests the best predictor for high test results was that LTPA had lasted for more than three years. Moreover, women reported more neuromuscular training than men, which explained to some extent the results of women in step squat, vertical jump, back endurance and ball throwing tests in which muscle strength partly accounts for the results. Nevertheless, these tests were mostly functional; optimal performance is based on good motor abilities and extreme physical output of muscle strength is not needed. In earlier studies (Suni et al. 1996) the same tests were used and revealed high sensitivity in differentiating fitness levels. These results also support the NG statement of Study IV: according to statistical analyses neither endurance nor neuromuscular types of LTPA affected any of the motor abilities.

As the panellists of NG proposed, a variety of exercise modes is beneficial both for training motor abilities and physical fitness, but when the training is specific it affects specific characteristics, i.e. specific neuromuscular training manifests in muscle strength. Suni et al. (1999) found that neuromuscular exercises were associated with good postural balance performance in women. Recently Lindström et al. (2009) compared neuromuscular training also including ball games, aerobic exercises, and lifestyle activity and fitness levels of middle-aged men and women with postural balance and functional leg strength using the same tests as in Study V. Neuromuscular training was associated with stable static and dynamic postural balance, and functional leg strength in both women and men. In our study neuromuscular exercises and ball games were studied independently, and the finding was that only those men who had played several ball games achieved higher results in tests.

The endurance type exercise modes, especially walking for fitness, were the most frequent of all the exercise modes both for women and men. This parallels other surveys on LTPA (Bijnen et al. 1998). In Study IV many endurance exercise modes were presumed to make minor demands on motor abilities. Furthermore, on the basis of Study V, endurance training alone does not explain any motor abilities. This concurs with the findings of Picard and Strick (2003) concerning the complexity of movements. Tasks that involve minimal motor demands, such as walking, are performed with ease and do not need much information processing, do not contribute to the development of motor abilities (Picard & Strick 2003). This finding also supports the theoretical evaluation of the NG statement concerning the determinants or training effects of different exercise modes. Of the physical fitness component endurance training indicated a better aerobic fitness trend for men in the 2 km walking test. Yet, walking and other types of endurance exercises are preferred LTPA modes with numerous health-related benefits and significant potential in reducing the incidence of chronic disease when the intensity of exercising is high enough (Lee & Buchner 2008).

Of the motor ability tests those for shoulder flexibility and rhythm coordination were the only tests having no association with R- or F-LTPA. Flexibility has also been found to remain at the same level from adolescence to adulthood (Mikkelson et al. 2006) and is partly determined because of genetic factors (Chatterjee & Das 1995). Moreover, rhythm coordination is needed when the movement should be timed precisely. This ability is inherent and may be determined by genetics, and therefore specific exercises have no notable affect. It seems that precision in relation to simple metric rhythms is more accurately produced than to complex rhythms even with practice (Grahn & Brett 2007, Chen et al. 2008). Grahn and Brett (2008) report that 74% of simple rhythms and 53% of complex rhythms were correctly performed, which supports our findings. However, our rhythm coordination test consisted of complex motor activities, tapping and marching simultaneously in a given rhythm, and probably needed more cognitive processes and attention (Serrien et al. 2007), which explained the lower rates.

Overall, Studies IV and V indicate that different exercise modes consist of independent motor abilities, and motor abilities benefit from specific exercising. It seems that due to heredity some people have apt motor abilities and high level of proficiency even without former training (Fox et al. 1996). In Study V heredity was not examined, but the results showed that exercise modes that require many motor abilities associated with better results of motor performance tests.

6.4 Perspectives related to physiotherapy and rehabilitation

These motor performance tests were selected in order to measure motor abilities among middle-aged population and provide physiotherapists with a basic tool to determine e.g. postural balance, rhythm coordination, and agility apart from other physical fitness components.

Different components of motor abilities and performance are often considered to equal functioning, likewise indicators of high functioning (Leino-Arjas et al. 2004). Studies II and III especially were aimed at clinical physiotherapy practice in order to develop tests for evaluating function, motor tasks and mobility items in TBI rehabilitation. Patients having recovered physically well from TBI may seem physically normal, but may have significant problems and abnormalities in motor or sensory performance when participating in premorbid motor activities. Yet these problems may go unidentified even in other functional assessment and ability scales, such as the Functional Independence Measure (FIM) or the Functional Assessment Measure (FAM). Their scores do not distinguish physically well-functioning patients well enough. Recently a new approach to the precise assessment of patient-related outcomes, i.e. computerized adaptive testing (CAT), has been developed in accordance with the ICF model (Jette 2008). This is an appropriate tool for monitoring the functioning with predefined items of outcome questions. However, so far no widely accepted standardized motor performance screening tests for adult patients with TBI are available for clinical use. Moreover, it is probable that similar diffuse deficiencies in motor performance may be observed in patients with other diagnoses than TBI, e.g. patients with different types of stroke, patients using drugs affecting motor performance, or these tests could be used to follow-up the motor abilities as an indicator of general motor functioning in aging.

Referring to the context of ICF (WHO 2001) this test battery could also be interpreted as a measure of activity. The ICF framework was established in order to achieve a common understanding between different professionals in rehabilitation and science, and provides a tool in terms of biopsychosocial model to better understand ”body functions and structures and activities and participation” (Stucki et al. 2007).

However, there is still a lack of appropriate and reliable field test methods for rehabilitation for operationalizing and measuring different subdomains of ICF (Quinn & Sullivan 2000, Jette 2008, Jette et al. 2009). From this viewpoint on ICF, these tests indicate functional status and may be used to conceptualise aspects of motor performance related to the components of activity and participation in ICF frames.

6.5 Methodological considerations

The test battery of motor performance was wide and covered several motor abilities, which were based on a theoretical model. However, parallel elements and similar test items have been used in other studies on children (Fleishman 1964, Beunen et al. 1997, Reed & Metzker 2004, Tammelin 2005) in order to measure motor performance. Tests measuring physical fitness were included in this study to ascertain the fitness levels of the participants and especially if the groups differed significantly. In all studies we evaluated the data from different viewpoints and used a wide range of statistical analyses as recommended (Hopkins 2000).

Some limiting aspects of these studies should be conceded. In Study I the homogeneity of the participants became restrictive for the analyses of three tests, and those tests were excluded. In an earlier study (n=498), the standing on one leg test was used. It had acceptable test-retest reproducibility (CV 5%) and a moderate amount of variability [mean difference between testing days 3.7s (95% CI -2.2 – 9.6) was discovered (Suni et al. 1996). In our study most of the participants scored maximum points, and therefore the test was excluded from further analyses. In addition, the other two excluded tests had small between-participants variation which diminished the ICC coefficient.

Furthermore, it should be noted that the TBI studies (II and III) were conducted among men, and generalisation to women concerning the evaluation of motor performance should be made with caution. Another concern is that the representativeness of the results is limited due to small sample size so the results should be interpreted indicatively.

In the nominal group study (IV) the variety in the backgrounds of the panelists provided alternative perspectives. However, it may be that specialists with different backgrounds emphasized some aspects in the evaluation in different ways. For instance, orienteering or basketball may have been rated to have more potential than in this evaluation. The list of exercise modes in the NG study is in line with a study of 3,345 Finnish men and women (Miranda et al. 2001). Even if the variety of exercise modes was wide, their connections with cultural and environmental circumstances, such as fashion, settings, equipment and natural conditions are relevant.

In Study V the selection and distribution of participants into inactive and active succeeded well regarding activity levels and the corresponding results of the fitness tests. The study groups represented on average the distribution of Finnish population at that age. Furthermore, the consistency of the reported number of years of exercising, the sum of lifetime exercise modes and the mean exercising hours per week seems to be high (Ropponen et al. 2001, Bowles et al. 2004). Yet the results are indicative due to the limitation of retrospective data concerning lifelong exercising. A confounding factor is that many exercise modes had been practised concurrently and the effects on motor abilities could be mixed. Concerning the effects on motor abilities, it still remains unclear if the participants had chosen the exercise modes because they had the motor abilities or if those abilities were practised by the exercise modes selected.

6.6 Implications for further studies

Motor abilities are the most important for functioning but there are only few studies on motor abilities and measuring the motor performance of adults. In the future, motor abilities should be studied among population of different ages. The test battery used in this dissertation was quite wide and comprehensive for motor performance and single tests were found to be reliable and feasible for field testing. However, data collected from a larger study population and different age groups in order to obtain reference values are needed. It would be also worthwhile to conduct a study on how motor ability tests correlate separately with each other.

Although the associations between R-LTPA (computed as METh $\cdot$wk^{-1}) and the test items were analysed in this dissertation, there still is still a lack of data defining both the shape of the dose-response curve at greater amounts and intensities of activity for most motor abilities and health outcomes. Most current physical activity recommendations focus on a minimal or target amount/intensity of activity that is beneficial, but do not address questions of optimal or maximal benefits. Therefore more studies are needed to clarify the dose-response of physical activity defined as MET-minutes per week or intensity, frequency, duration, and sessions. To be exact about the intensity of recent activity, activity monitors collecting data for several days might be worthwhile.

Furthermore, the NG consensus statement is indicative, and primarily as a qualitative estimate. The results of this evaluation in relation to observed data need to be tested in order to obtain more supporting evidence for requirements of different exercise modes. This can be confirmed by analysing the general or specific characteristics of the most commonly practised exercise modes by video motion analyses. In addition to the motion analyses the effects of exercise modes on motor abilities could be examined in intervention studies.

To increase the representativeness of the results of the TBI group the usefulness and validity of the test battery should be investigated in larger prospective studies and in longitudinal intervention rehabilitation studies. Moreover, an essential goal for future research would be to ascertain how cognitive pathways are connected neurally with motor pathways by using, for example, fMRI or diffuser tensor imaging techniques. Further research is needed to compare different subgroups of TBI patient, in order to determine and evaluate the precise effects of TBI rehabilitation on motor abilities and performance.

7 CONCLUSIONS AND RECOMMENDATIONS

This study was one of the first to elaborate a test battery of motor abilities for middle-aged men and women, to evaluate participants´ motor abilities, and to ascertain the contribution of present and past leisure physical activities and different exercise modes to motor abilities. The significance of motor ability training has not been emphasized enough with respect to the middle-aged. As a clinical application, tests of postural balance, agility and rhythm coordination were used to assess the motor performance of men with mild or moderate TBI. Referring to the aims of this dissertation, the conclusions and recommendations can be summarized as follows:

1. The test battery for assessing motor abilities was consistent, feasible and acceptable. Its repeatability improves when the participant had an opportunity to practise the test, and when unambiguous test instructions are given. The consistency of the tests with quantitative scores seems to be better than those with qualitative scores. The discrepancy between raters decreases if the evaluation criteria for qualitative test performance are standardized. (I,II)

2. The motor performance tests provide physiotherapists with basic tools to assess and detect deficiencies in the motor performance of physically well-recovered TBI patients. The figure-of-eight run, fast rhythm coordination and tandem walking forwards tests were the best tests for screening out men with TBI from healthy controls. (III)

3. A systematic evaluation of different exercise modes in terms of motor abilities forms a theoretical basis that indicates a wide variety of less demanding and safe exercise modes which are available for sedentary middle-aged people to start more physically active lifestyle. Walking, cycling, swimming and jogging are easy to start but have only limited training effects on motor abilities. Rollerskating, downhill skiing and martial arts challenge all motor abilities but may not be the preferred exercise modes for beginners. (IV)

4. Participants who had been physically active and practised different exercise modes achieved higher results in the tests of motor abilities than their inactive counterparts. Endurance training and muscle strengthening exercises are not sufficient alone to improve motor abilities while playing ball games is beneficial for many components of motor ability. (V)

TIIVISTELMÄ

Tieteellinen näyttö liikunnan merkityksestä terveyden ja toimintakyvyn ylläpitäjänä ja edistäjänä on vahvistunut. Nykyisin liikuntaa käytetään useiden sairauksien hoidossa ja kuntoutuksessa. Kuitenkin liikkumiseen liittyviä liikehallintakykyjä ja liikunnan vaikutusta niihin on tutkittu aikuisilla hyvin vähän. Liikehallintakyvyt tarkoittavat suhteellisen pysyviä ominaisuuksia, jotka ovat toiminta- ja tehtäväsuuntautuneita. Ne tarkoittavat tässä yhteydessä laaja-alaisempaa kykyä suorittaa motorisia toimintoja tarkasti, tehokkaasti ja taloudellisesti kuin pelkästään yksittäiseen liikuntalajiin liittyvä taito-ominaisuus. Liikehallintaa säätelee sekä hermolihas- ja havaintomotorinen toiminta että aivojen ohjausprosessit. Liikehallinnassa voidaan erottaa viisi peruskykyä: kinesteettinen erottelukyky, suuntautumiskyky, tasapainokyky, reaktiokyky ja rytmi-koordinaatio, joita voidaan myös yhdistellä tai muunnella tarkoituksenmukaisesti.

Tämän väitöskirjan tarkoitus oli selvittää, miten fyysinen aktiivisuus tai spesifi harjoittelu vaikuttaa keski-ikäisten (41-47 –v.) naisten (n=79) ja miesten (n=69) liikehallintaan. Kliinisenä sovelluksena tutkittiin Invalidiliiton Käpylän kuntoutuskeskukseen kuntoutusjaksoille tulleiden, traumaattisesta aivovauriosta hyvin toipuneiden mieskuntoutujien (n=34, keski-ikä 34 v) liikehallintaa, ja verrokeiksi mittauksiin kutsuttiin 36 tervettä miestä (keski-ikä 31 v). Edellä mainitut tutkimukset toteutettiin poikkileikkausasetelmina.

Liikehallinnan kykyalueiden tutkimisessa käytettiin testipatteristoa, joka oli valittu kirjallisuuskatsauksen perusteella yhteensä kymmenen liikehallintaa mittaavaa testiä. Testistön toistettavuus ja luotettavuus selvitettiin kahdessa eri tutkimusjoukossa, joista toisessa osallistujina oli yhteensä 25 naista ja miestä ja toinen toteutettiin aivotraumakuntoutujilla ja heidän verrokeillaan. Testien toistettavuus molemmissa aineistossa oli hyvä kahden eri testikerran välillä (test-retest –asetelma) sekä saman testaajana että eri testaajien välillä (intra-rater/inter-rater -asetelma. Lisäksi niin sanotun näennäisryhmän tekniikalla (nominal group technique) avulla laadittiin teoreettinen, kahdeksan liikunta- ja terveystieteen asiantuntijan arviointiin perustuva yhteenveto siitä, mitä liikehallintakykyjä tavallisimmin harrastetut liikuntalajit edellyttävät ja mitä ne tavoitteellisesti harrastettuna kehittävät.

Keski-ikäisiltä naisilta ja miehiltä selvitettiin kyselylomakkeella nykyisen fyysisen aktiivisuuden määrää, intensiteettiä, laatua, aikuisiällä ensisijaisesti harrastettuja liikuntalajeja sekä itsearviota siitä, montako vuotta on säännöllisesti harrastanut liikuntaa. Nykyisen liikuntaharrastuksen tietojen ja testitulosten perusteella selvitettiin ensiksi fyysisen aktiivisuuden määrän ja rasittavuuden (metabolinen ekvivalentti (MET)-tunteja viikossa) yhteyttä liikehallintakykyihin. Suuri MET-tuntimäärä viikossa oli selvästi yhteydessä erityisesti vakaaseen staattiseen tasapainoon ja miehillä lisäksi nopeaan juoksuketteryyteen. Lisäksi suurimmassa osassa liikehallintakykyjä mittaavissa testeissä korkeamman tuloksen sai mitä suurempi MET-tuntimäärä viikossa oli. Miehillä erityi-

sesti aiempi liikuntaharrastus pallopelien parissa näytti selittävän parhaiten hyvää tulosta lähes kaikissa liikehallintakykytesteissä. Vastaavasti naisilla selittäväksi tekijäksi dynaamisessa tasapainossa ja ketteryysjuoksussa osoittautui liikunta-aktiivisuus, joka oli jatkunut monen vuoden ajan säännöllisesti. Erikseen tarkasteltuina spesifeistä liikuntamuodoista naisilla lihaskuntoharjoittelu selitti ponnistushyppytestissä korkeammalle hyppäämistä ja pelilajit dynaamista tasapainoa mittaavan etuperin tandem-kävelyn nopeampaa kävelyvauhtia.

Liikehallintatestien kuntoutukseen sovelletussa tutkimuksessa aivotraumakuntoutujat olivat tilastollisesti merkitsevästi hitaampia juoksunopeudessaan ketteryystestissä (8-juoksu), pysyivät vähemmän aikaa staattisessa seisoma-asennossa tasapainotestissä yhdellä jalalla, selviytyivät dynaamisesta tandem-kävelytehtävästä hitaammin sekä suorittivat rytmi-koordinaatiotestin epätarkemmin kuin verrokkiryhmäläiset. Näiden tulosten perusteella testituloksista laskettiin vielä sensitiivisyyteen ja spesifisyyteen perustuvat raja-arvot, joiden perusteella voidaan jatkaa tarkempia liikehallintakykyjen ongelmien diagnosointia kliinisessä työssä.

Nominal group – asiantuntijapanelistien tekemän liikuntalajien vaativuuden arvioinnissa lähtökohtana oli vertailla tavallisimmin keski-ikäisten naisten ja miesten harrastamia liikuntalajeja niiden liikehallintakykyominaisuuksien suhteen toisiinsa. Arvioinnin perusteella vähiten liikehallintakykyjä edellyttäviksi lajeiksi panelistit arvioivat kävelyn, pyöräilyn, uimisen ja hölkän. Liikehallintakyvyiltään vaativimmiksi lajeiksi arvioitiin rullaluistelu, laskettelu ja itsepuolustuslajit, jotka panelistien mielestä edellyttivät kaikkia viittä liikehallintakykyä.

Edellä olevien osatutkimusten tulosten perusteella voidaan todeta valittujen testien toistettavuus olevan riittävä aikuisten liikehallinnan mittaamiseen peräkkäisillä mittauskerroilla. Aivotraumakuntoutujilla tehdyn tutkimuksen perusteella liikehallintaa mittaava testistö soveltuu myös fysioterapeuteille kliiniseen työhön. Liikuntalajien ominaisuuksien arvioinnin mukaan liikuntaa tulisi harrastaa monipuolisesti, jolloin se kehittää monia liikehallinnan ominaisuuksia. Lisäksi fyysisesti intensiivinen ja säännöllinen spesifi harjoittelu sekä liikunta-aktiivisuus näyttivät vaikuttavan suotuisasti liikehallintaan. Lisätutkimuksia kuitenkin tarvitaan selvittämään, miten perintötekijät mahdollisesti vaikuttavat liikehallintakykyihin sekä miten harjoittelun ja liikunnan lisääminen aikuisiällä vaikuttavat niihin.

REFERENCES

Afifi A, Bergman R. 2005. Functional Neuroanatomy, 2nd edition: Text and Atlas (LANGE Basic Science). The Mc Graw-Hill Companies, USA.

Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O´Brien WL, Bassett DR Jr, Schmitz KH, Emplaincourt PO, Jacobs DR JR, Leon AS. 2000. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 32, (9 Suppl), S498-S516.

Alaranta H, Koskinen S, Leppänen L, Palomäki H. 2000. Nationwide epidemiology of hospitalized patients with first-time traumatic brain injury with special reference to prevention. Wien Med Wschr 150 (22), 444-448.

Armitage P, Berry G, Matthews JNS. 2002. Statistical methods in medical research. 4th ed. Blackwell Science, United Kingdom.

Atkinson G, Nevill AM. 1998. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med 26 (4), 217-238.

Azouvi P, Couillet J, Leclerq M, Martin Y, Asloun S, Rousseaux M. 2004. Divided attention and mental effort after severe traumatic brain injury. Neuropsychologia 42 (9), 1260-1268.

Baquet G, Twisk JWR, Kemper HCG, van Praagh E, Berthoin S. 2006. Longitudinal follow-up of fitness during childhood: Interaction with physical activity. Am J Hum Biol 18 (1), 51-58.

Bateman A, Culpan FJ, Pickering AD, Powell JH, Scott OM, Greenwood RJ. 2001. The effect of aerobic training on rehabilitation outcomes after recent severe brain injury: a randomized controlled evaluation. Arch Phys Med Rehabil 82 (2), 174-182.

Beunen G, Ostyn M, Simons J, Renson R, Claessens AL, Vanden Eynde B, Lefevre J, Vanreusel B, Malina RM, van't Hof MA. 1997. Development and tracking in fitness components: Leuven longitudinal study on lifestyle, fitness and health. Int J Sports Med 18 (S3), S171-178.

Biering-Sørensen F. 1984 Physical measurements as risk indicators for low-back trouble over a one-year period. Spine 9 (2),106-119.

Bijnen FC, Feskens EJ, Caspersen CJ, Giampaoli S, Nissinen AM, Menotti A, Mosterd WL, Kromhout D. 1996. Physical activity and cardiovascular risk factors among elderly men in Finland, Italy, and the Netherlands. Am J Epidemiol 143 (6), 553-561.

Bland JM, Altman DG. 1986. Statistical methods for assessing agreement between two methods of measurement. Lancet 1 (8476), 307-310.

Bouchard C, Shephard R, Stephens T (eds.) 1994. Physical activity, fitness and health : international proceedings and consensus statement. Champaign, Il : Human Kinetics.

Bös K. 1987. Handbuch sportmotorischer Tests. Verlag für Psychologie, Göttingen.

Bowles HR, FitzGerald SJ, Morrow JR, Jackson AW, Blair SN. 2004. Construct validity of self-reported historical physical activity. Am J Epidemiol 3 (160), 279-286.

British Standards Institution. 1979. Precision of test methods I: Guide for the determination and reproducibility for a standard test method (BS 5497, part 1) British Standards Institution, London.

Bruininks RH. 1978. Bruininks-Oseretsky Test of motor proficiency examiner´s manual. American Guidance Service, Circle Pines, MN.

Bruininks RH, Bruininks BD. 2006. Bruininks-Oseretsky Test of motor proficiency, second edition (BOT-2). American Guidance Service, Circle Pines MN.

Burton AW, Miller DE. 1998. Movement skill assessment. Champaign, IL. Human Kinetics.

Burton AW, Rodgerson RW. 2001. New perspectives and the assessment of movement skills and motor abilities. APAQ 18 (4), 347-365.

Campbell M, Parry A. 2005. Balance disorder and traumatic brain injury: preliminary findings of a multi-factorial observational study. Brain Inj 19 (13), 1095-1104.

Cantin J-F, McFadyen BJ, Doyon J, Swaine B, Dumas D, Vallée M. 2007. Can measures of cognitive function predict locomotor behaviour in complex environments following a traumatic brain injury? Brain Inj 21 (3), 327-334.

Caspersen CJ, Powell KE, Christenson GM. 1985. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 100 (2), 126-131.

Cassidy JD, Carroll LJ, Peloso PM, Borg J, von Holst H, Holm L, Paniak C, Pépin M. 2004. WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehabil Med 43 Suppl, 28-60.

Chatterjee S, Das N. 1995. Physical and motor fitness in twins. Jpn J Physiol 45 (3), 519-534.

Chen JL, Penhune VB, Zatorre RJ. 2008. Listening to musical rhythms recruits motor regions of the brain. Cereb Cortex 18 (12), 2844-2854.

Consensus conference. 1999. Rehabilitation of persons with traumatic brain injury. NIH consensus development panel on rehabilitation of persons with traumatic brain injury. JAMA 282 (10), 974-983.

Davids K, Glazier P, Araújo D, Bartlett R. 2003. Movement systems as dynamical systems. The functional role of variability and its implications for sports medicine. Sports Med 33(4) 245-260.

Dombovy M, Olek A. 1996. Recovery and rehabilitation following traumatic brain injury. Brain Inj 11 (5), 305-318.

Downs SB, Wood TM. 1996. Validating a Special Olympics volleyball skills assessment test. APAQ 13 (2),166-179

Engström L-M, Ekblom B, Forsberg A, v Koch M, Seger J. 1993. Livsstil-Prestation-Hälsa. LIV 90. Rapport i motionsvanor, fysisk prestationsförmåga och hälsotillstånd bland svenska kvinnor och män i åldrarna 20-65 år. Stockholm.

EUROFIT. Handbook for the EUROFIT Tests of Physical Fitness. 1993. Committee of experts on sports research. 2nd edition, Strasbourg: Council of Europe.

Finch E, Brooks D, Stratford PW, Mayo NE. 2002. Physical rehabilitation outcome measure to enhanced clinical decision making. 2nd edition, Canadian Physiotherapy Association. Toronto, Lippincott Williams and Wilkins.

Fleishman EA. 1964. The Structure and Measurement of Physical Fitness. Englewood Cliffs, N.J. Prentice–Hall.

Fleishman EA. 1967. Performance assessment based on empirically derived task taxonomy. Human Factors 9 (4), 349-366.

Fleishman EA, Quaintance MK. 1984. Taxonomies of human performance. The description of human tasks. New York, Academic Press.

Fonseca ST, Magee D, Wessel J, Reid D. 1992. Validation of a performance test for outcome evaluation of knee function. Clin J Sport Med 2, 251-256.

Fox PW, Hershberger SL, Bouchard TJ. 1996. Genetic and environmental contribution to the acquisition of a motor skill. Nature 384 (6607), 356-358.

Gauvin MG, Riddle DL, Rothstein JM. 1990. Reliability of clinical measurements of forward bending using the modified fingertip-to-floor method. Phys Ther 70 (7), 442-447.

Geiger RA, Allen JB, O´Keefe J, Hicks RR. 2001. Balance and mobility following stroke: effects of physical therapy interventions with and without biofeedback/forceplate training. Phys Ther 81 (4), 995-1005.

Geurts AC, Knoop JA, van Limbeek J. 1999. Is postural control associated with mental functioning in the persistent postconcussion syndrome? Arch Phys Med Rehabil 80 (2), 144-149.

Gfeller JD, Cradock MM. 1998. Detecting feigned neuropsychological impairment with the Seashore Rhythm Test. J Clin Psych 54 (4), 431-438.

Glenmark B, Hedberg G, Jansson E. 1994. Prediction of physical activity level in adulthood by physical characteristics, physical performance and physical activity in adolescence: an 11 year follow-up study. Eur J Appl Physiol 69 (6), 530-538.

Grahn JA, Brett M. 2007. Rhythm and beat perception in motor areas of the brain. J Cogn Neurosci 19 (5), 893-906.

Hagströmer M, Oja P, Sjöström M. 2007. Physical activity and inactivity in an adult population assessed by accelerometry. Med Sci Sports Exerc 39 (9), 1502-1508.

Haley SM, Osberg JS. 1989. Kappa coefficient calculation using multiple ratings per subject: A special communication. Phys Ther 69 (11), 970- 974.

Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A. 2007. Physical activity and public health: updated recommendation for adults from the American College of

Sports Medicine and The American Heart Association. Med Sci Sports Exerc 39 (8), 1423-1434.

Helakorpi S. Laitalainen E, Uutela A. 2010 Health behaviour and health among the Finnish adult population, Spring 2009. National Institute for Health and Welfare (THL), Report 7/2010, Helsinki.

Heyward VH. 2005. Advanced fitness assessment and exercise prescription. 5th edition, Champaigne, IL: Human Kinetics, 44-45.

Hirtz P. 1985. Die Koordinative Fähigkeiten in Schulsport. Vielseitig-variationsreich-ungewohnt. Berlin, Volk und Wissen Volkseigener Verlag.

Hopkins WG. 2000. Measures of reliability in sports medicine and science. Sports Med 30 (1), 1-15.

Hulley SB, Cumming SR, Browner WS, Grady DG, Hearst N. 2000. Designing clinical research: an epidemiologic approach. 2nd edition, Baltimore: Lippincott Williams and Wilkins.

Husu P, Suni J, Pasanen M, Miilunpalo S. 2007. Health-related fitness tests as predictors in long-distance walking among high-functioning older adults. Aging Clin Exp Res 19 (6), 444-450.

International Organization for Standardization. 2004. Ergonomics of the thermal environment-determination of metabolic rate. ISO/FDIS 8996. Geneva: ISO.

Jette AM, Haley SM, Ni P, Olarsch S, Moed R. 2008. Creating a computer adaptive test version of the late-life function and disability instrument. J Gerontol A Biol Sci Med Sci 11 (63), 1246-1256.

Jette AM. Toward a common language of disablement. 2009. J Gerontol A Biol Sci Med Sci 11 (64), 1165-1168.

Jette DU, Halbert J, Iverson C, Miceli E, Shah P. 2009. Use of standardized outcome measures in physical therapist practice: perceptions and applications. Phys Ther 89 (2), 125-135.

Jones J, Hunter D. 1995. Consensus methods for medical and health services research. BMJ 311 (7001), 376-380.

Kandel ER, Schwartz JH, Jessell TM. 2000. Principles of neural science. 4th edition, McGraw-Hill, US.

Karinkanta S, Heinonen A, Sievänen H, Uusi-Rasi K, Pasanen M, Ojala K, Fogelholm M, Kannus P. 2007. A multi-component exercise regimen to prevent functional decline and bone fragility in home-dwelling elderly women: randomized, controlled trial. Osteoporos Int 18 (4), 453-462.

Kemper HCG, de Vente W, van Mechelen W, Twisk JWR. 2001. Adolescent motor skill and performance: Is physical activity in adolescence related to adult physical fitness? Am J Hum Biol 13 (2), 180-189.

Kioumourtzoglou E, Kourtessis T, Michalopoulou M, Derri V. 1998. Differences in several perceptual abilities between experts and novices in basketball, volleyball and water-polo. Perceptual Mot Skills 86 (3 Pt 1), 899-912.

Laukkanen R. 1993. Development and evaluation of a 2-km walking test for assessing maximal aerobic power of adults in field conditions. Tampere and Kuopio: Kuopio University Publications D. Medical Sciences 23. UKK Institute and University of Kuopio.

Lee IM, Buchner DM. 2008. The importance of walking to public health. Med Sci Sports Exerc 40 (7), S512-518.

Lefevre J, Beunen G, Steens A, Claenssens A, Renson R. 1990. Motor performance during adolescence and age thirty as related to age at peak height velocity. Ann Hum Biol 17 (5), 423-435.

Leino-Arjas P, Solovieva S, Riihimäki H, Kirjonen J, Telama R. 2004. Leisure time physical activity and strenuousness of work as predictors of physical functioning: a 28 year follow up of a cohort of industrial employees. Occup Environ Med 61 (12), 1032-1038.

Lemmink KAPM, Kemper HCG, de Greef MHG, Rispens P, Stevens M. 2003. Reliability of the Groningen fitness test for the elderly. J Aging Phys Act 9, 194-212.

Lindström PJ, Suni JH, Nygård CH. 2009. Associations of leisure-time physical activity with balance and lower extremity strength: a validation of the neuromuscular part of the Physical Activity Pie. JPAH 6 (4), 493-502.

Läärä E, Aro S. 1988. Mittausmenetelmien hyvyys ja sen tilastollinen arviointi. Duodecim 104, 40-52.

Magill RA. 2004. Motor learning and control. Concepts and applications. 7th edition, New York, McGraw-Hill.

Madureira MM, Takayama L, Gallinaro AL, Caparbo VF, Costa RA, Pereira RM. 2007. Balance training program is highly effective in improving functional status and reducing the risk of falls in elderly women with osteoporosis: a randomized controlled trial. Osteoporos Int 18 (4), 419-425.

Malina RM. 1996. Tracking of physical activity and physical fitness across the lifespan. Res Q Exerc Sport 67 (3), S48-57.

Marttila J, Laitakari J, Nupponen R, Miilunpalo S, Paronen O. 1998 The versatile nature of physical activity – on the psychological, behavioural and contextual characteristics of health-related physical activity. Patient Educ Couns 33 (Suppl 1), S29-S38.

Masanic C, Bayley M. 1998. Interrater reliability of neurologic soft signs in an acquired brain injury population. Arch Phys Med Rehabil 79 (7), 811-815.

McFadyen BJ, Swaine B, Dumas D, Durand A. 2003. Residual effects of a traumatic brain injury on locomotor capacity. A first study of spatiotemporal patterns during unobstructed and obstructed walking. J Head Trauma Rehabil 18 (6), 512-525.

McGuire SA, Gronseth GS, Adams A. 1995. Incidence of traumatic head injury in a defined population. Neurology 45 (Suppl 4), A328.

Miilunpalo S, Nupponen R, Laitakari J, Marttila J, Paronen O. 2000. Stages of change in two modes of health-enhancing physical activity: methodological aspects and promotion implications. Health Education Research 15 (4); 435-448.

Mikkelsson L, Kaprio J, Kautiainen H, Kujala U, Mikkelsson M, Nupponen H. 2006. School fitness tests as predictors of adult health-related fitness. Am J Hum Biol 18 (3), 342-349.

Miranda H. Viikari-Juntura E, Martikainen R, Takala E-P, Riihimäki H. 2001. Physical exercise and musculoskeletal pain among forest industry workers. Scand J Med Sci Sports 11 (4), 239-246.

Nagi S. 1965. Some conceptual issues in disability and rehabilitation. In: Sussman M (Ed.) Sociology and rehabilitation. Washington, DC; American Sociological Association, 100-113.

Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ. 1994. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. A randomized controlled trial. JAMA 272 (24), 1909-1914.

Oja P, Laukkanen R, Pasanen M, Tyry T, Vuori I. 1991. A 2-km walking test for assessing cardiorespiratory fitness of healthy adults. Int J Sports Med 12 (4), 356-362.

Parker TM, Osternig LR, Lee HJ, Donkelaar P, Chou LS. 2005. The effect of divided attention on gait stability following concussion. Clin Biomech 20 (4), 389-395.

Pasanen K. Parkkari J, Pasanen M, Hiilloskorpi H, Mäkinen T, Järvinen M, Kannus P. 2008. Neuromuscular training and the risk of leg injuries in female floorball players: cluster randomised controlled study. BMJ 337 (7661), 96–99.

Pasanen K. Parkkari J, Pasanen M, Kannus P. 2009. Effect of a neuromuscular warm-up programme on muscle power, balance, speed and agility – A randomised controlled study. Br J Sports Med 43 (13), 1073-1078.

Pate RR, Pratt M, Blair, SN, Haskell WL, Macera CA, Bouchard C, Buchner D, Ettinger W, Heath GW, King AC, et al. 1995. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA 273 (5), 402–407.

Paterson DH, Jones GR, Rice CL. 2007. Ageing and physical activity: evidence to develop exercise recommendations for older adults. Can J Public Health 98 (Suppl 2), S69-S108.

Picard N, Strick PL. 2003. Activation of the supplementary motor area (SMA) during performance of visually guided movements. Cereb Cortex 13 (9), 977-986.

Ponsford JL, Olver J, Curran C. 1995. A profile of outcome: 2 years after traumatic brain injury. Brain Inj 9 (1), 1-10.

Quinn B, Sullivan J. 2000. The identification by physiotherapists of the physical problems resulting from a mild traumatic brain injury. Brain Inj 14 (12), 1063-1076.

Reed JA, Metzker A. 2004. Relationships between physical activity and motor skills in middle school children. Percept Mot Skills 99 (2), 483-494.

Reitan RM, Wolfson D. 1989. The Seashore Rhythm Test and brain functions. Clin Neurophysiol 1 (3), 70-78.

Rinne M. 1996. Liikuntataitojen ja –kykyisyyden sekä terveyskunnon mittaamiseen soveltuvat testit. Kirjallisuuskatsaus. Moniste Opetusministeriön apurahahakemukseen. (Handout in Finnish.)

Risberg MA, Holm I, Ekeland A. 1995. Reliability of functional knee tests in normal athletes. Scand J Med Sci Sports 5 (1), 24-28.

Ropponen A, Levälahti E, Simonen R, Videman T, Battié MC. 2001. Repeatability of lifetime exercise reporting. Scand J Med Sci Sports 11 (3), 185-92.

Sargent DA. 1921. The physical test of a man. American Physical Education Review, 26, 188-194.

Schmidt RA, Lee TD. 2005. Motor control and learning. A behavioural emphasis. 4th edition, Champaign; IL; Human Kinetics.

Schneider S, Askew CD, Abel T, Mierau A, Strüder HK. 2010. Brain and exercise: a first approach using electrotomography. Med Sci Sports Exer 3 (42), 600-607.

Serrien DJ, Ivry RB, Swinnen SP. 2007. The missing link between action and cognition. Prog Neurobiol 82 (2), 95-107.

Shaffer LH. 1982. Rhythm and timing in skill. Psychol Rev 89 (2),109-22.

Sosin DM, Sniezek JE, Thurman DJ. 1996. Incidence of mild and moderate brain injury in the United States, 1991. Brain Inj 10 (1), 47-54.

Sosnoff JJ, Broglio SP, Ferrara MS. 2008. Cognitive and motor function are associated following mild traumatic brain injury. Exp Brain Res 187 (4), 563-571.

Stucki G, Cieza A, Melvin J. 2007. The International Classification of Functioning, Disability and Health: a unifying model for the conceptual description of the rehabilitation strategy. J Rehabil Med 39 (4), 279-285.

Suni JH. Oja P, Laukkanen RT, Miilunpalo SI, Pasanen ME, Vuori IM, Vartiainen TM, Bös K. 1996. Health-related fitness test battery for adults: aspects of reliability. Arch Phys Med Rehabil 77 (4), 399-405.

Suni JH, Oja P, Miilunpalo SI, Pasanen ME, Vuori IM, Bös K. 1999. Health-related fitness test battery for middle-aged adults: associations with physical activity patterns. Int J Sports Med 20 (3), 183-91.

Tammelin T. 2005. A review of longitudinal studies on youth predictors of adulthood physical activity. Int J Adolesc Med Health 17 (1), 3-12.

Tanji J. 1996. New concepts of the supplementary motor area. Curr Opin Neurobiol 6 (6), 782-787.

Tankus A, Yeshurun Y, Flash T, Fried I. 2009. Encoding of speed and direction of movement in the human supplementary motor area. J Neurosurg. 110 (6), 1304-1316.

Tegner Y, Lysholm J, Lysholm M, Gillquist J. 1986. A performance test to monitor rehabilitation and evaluate anterior cruciate ligament injuries. Am J Sports 14 (2), 156-159.

Thaut MH, Demartin M, Sanes JN. 2008. Brain networks for integrative rhythm formation. PLoS One 3 (5), e2312.

Thomson K, Watt A, Liukkonen J. 2008. Skill-related differences between athletes and nonathletes in speed discrimination. Percept Mot Skills 107 (3), 893-900.

Twisk JWR, Kemper HCG, van Mechelen W. 2000. Tracking of activity and fitness and the relationship with cardiovascular disease risk factors. Med Sci Sports Exerc 32 (8), 1455-1461.

UCLA. Introduction to SAS. Academic Technology Services, Statistical Consulting Group. Available from: http://www.ats.ucla.edu/stat/mult_pkg/faq/general/coefficient_of_variation.htm

U.S. Department of Health and Human Services. 1996. Physical activity and health: a report of the surgeon general. U.S. Department of Health & Human Services, Atlanta.

U.S. Department of Health and Human Services. 2008. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, 2008. Washington, DC. Available from: http://www.health.gov/paguidelines/Report/pdf/CommitteeReport.pdf

van der Horst K, Paw MJCA, Twisk JWR, van Mechelen W. 2007. A brief review on correlates of physical activity and sedentariness in youth. Med Sci Sports Exerc 8 (39), 1241-1250.

van Heuvelen MJ, Kempen GI, Ormel J, Rispens P. 1998.Physical fitness related to age and physical activity in older persons. Med Sci Sports Exerc 30 (3), 434-441.

Verbrugge LM, Jette A. 1994. The disablement process. Soc Sci Med 38 (1), 1-14.

Verstappen FTJ, van Santen-Hoeuft HMS, Bolwijn PH, van der Linden S, Kuipers H. 1997. Effects of a group activity program for fibromyalgia patients on physical fitness and well-being. J Musculoskel Pain 5 (4), 17-28.

Voorrips LE, Lemmink KAPM, van Heuvelen MJG, Bult P, Staveren WA. 1993. The physical condition of elderly women differing in habitual physical activity. Med Sci Sports Exerc 25 (10), 1152-1157.

Warburton DE, Charlesworth S, Ivey A, Nettlefold L, Bredin SS. 2010. A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. Int J Behav Nutr Phys Act, 7:39.

WHO. 2001. International Classification of Functioning, Disability and Health: ICF: Short version. Geneva, World Health Organization.

WHO. 2004. Global strategy on diet physical activity and health. Geneva, World Health Organization.

Wilmore JH. 2005. Differences between men and women for exercise testing and exercise prescription”. In Skinner JS (Ed.) Exercise testing and exercise prescription for special cases. Theoretical basis and clinical application. 3rd edition, Baltimore, MD: Lippincott Williams and Wilkins, 54-67.

Wilmore JH, Costill DL, Kenney WL. 2008. Physiology of Sport and Exercise. 4th edition, Champaigne, IL: Human Kinetics, 457-458.

Wolf U, Rapoport MJ, Schweizer TA. 2009. Evaluating the affective component of the cerebellar cognitive affective syndrome. J Neuropsychiatry Clin Neurosci 21 (3), 245-253.

APPENDICES

APPENDIX 1 Characteristics of participants (mean with SD) and the description of their leisure time physical activity (LTPA) and occupational status.

	Study I	Study II and III		Study V
		TBI	Healthy	
Men (n)	14	34	36	69
Age, years (SD)	54 (11)	34 (10)	31 (11)	43 (2)
Height, cm (SD)	177 (5)	177 (7)	178 (8)	178 (6)
Weight, kg (SD)	79 (11)	80 (15)	79 (13)	85 (10)
BMI, kg/m² (SD)	25 (3)	25 (4)	25 (3)	27 (3)
Weekly exercise, times (n)				
None	-	10	3	33
Once or twice	7	6	5	31
Three times or more	7	20	25	5
Occupational status (n)				
not working	7			11
sedentary or light work	5			35
moving or physically heavy work	2			23
Women (n)	11			79
Age, years (SD)	51 (6)			43 (2)
Height, cm (SD)	165 (5)			165 (5)
Weight, kg (SD)	68 (9)			69 (16)
BMI, kg/m² (SD)	25 (3)			26 (5)
Weekly exercise, times (n)				
None	-			44
Once or twice	7			27
Three times or more	4			8
Occupational status (n)				
not working	4			10
sedentary or light work	3			44
moving or physically heavy work	4			25

APPENDIX 2 Description of test items in order to measure the components of motor ability and physical fitness are as follows:

<u>*Postural balance*</u>

Standing on one leg (Suni et al. 1996) *:* The test is performed with the preferred leg. The participant stands on one leg with eyes open and arms relaxed by sides. Heel of the opposite foot is against the medial side of supporting leg at the level of the knee joint and the tight is rotated outwards. Balance time is measured in seconds with a stopwatch, and the upper limit for the trial is 60 seconds. If the limit is not reached the participant has a second trial, and the best time is used in the analyses. In the TBI studies the participant performs the test separately with both legs, starting with the right leg.

Standing on a narrow bar (Engström et al. 1993): The participant is asked to stand for 1 min on one leg on a narrow bar (width 2 cm, height 5 cm, and length 50 cm), with the other leg free and allowed to use the arms for balance. If he lost his balance and touched the floor with his free foot, the watch is stopped and restarted when the balanced position is achieved again. The numbers of restarts are registered. The test is performed only once.

Tandem walking forwards: To measure dynamic balance, the participant is instructed to place one foot in front of the other with the heel and toe of their shoes touching (tandem step), and walk as fast as possible along a 6-meter line without side touches or mistakes in tandem steps. The test is performed 3 times and the walking time of each trial is measured in seconds. The best result of 3 trials is used in the analyses.

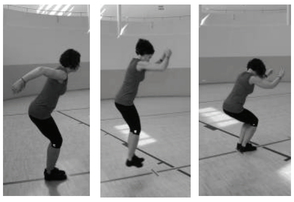
Tandem walking backwards (Nelson et al. 1994): The instructions and the conditions are the same as for tandem walking forwards, but the walking direction is backwards. The best result of 3 trials is used in the analyses.

<u>*Orientation*</u>

Vertical ball throw: The participant is asked to throw a ball with both hands upwards vertically 1 m and catch it five times continuously. The participant is requested to stand in place during the throwing but is allowed to move to catch the ball if necessary. The sum of scores is from 0 to 10 points: 2 points for each successful throw (standing in place), 1 point if the participants moved but catch the ball and 0 points if the participant does not catch the ball either when standing in place or when moving.

Ball bouncing test (Downs et al. 1996, Verstappen et al. 1997*)*: From a distance of 2 m, volleyball is bounced against a wall above a line 2 m high 20 times as fast as possible. The time (s) of performance is recorded.

<u>*Kinaesthetic differentiation*</u>



Standing broad jump: A baseline and distances of 50, 75 and 100 cm are marked by tape line. Each jump starts at the baseline and participant is asked to jump on the given distances landing on the exact mark. The accuracy of each jump is assessed according to the participants´ heels, which should be on the line. The sum of the scores is from 0 to 3 points: 1 point for each accurate jump and 0 point if the jump is inaccurate.

<u>*Sense of rhythm*</u>

Rhythm coordination test: The participant performs rhythm coordination test of the upper and lower extremities with marching and clapping hands to the rhythm of metronome signal. At first, the participant is asked to march in accordance with the slow rhythm (92 beats/min) for 30 s, a step for every beat, and then continues marching for another 30 s and claps hands together on every other beat. After the slow phase the tester resets the metronome at a fast rhythm (138 beats/min) and the participant repeats the fast rhythm phase with the same procedure as in the slow rhythm phase. Both rhythm phases are performed only once. The performances are scored according to the accuracy for both the slow and fast rhythm phases in points. The score for both phases is 0 to 8 points and the sum of the both scores can be from 0 point to 16 points.

<u>*Agility and explorative muscle strength*</u>

Figure-of-eight run (Tegner et al. 1986): To measure agility, the participant is instructed to run a course in a figure-of-eight, marked with 2 traffic cones placed 10 m apart with the start/finish line next to one of the cones. The stopwatch is started concurrently with the starting signal, and the participant runs to the second cone, circulates it, and returns to the starting line around the first cone. The stopwatch is stopped when the participant crosses the starting line again. The time is recorded in seconds. The test is performed 3 times with a short rest between each trial.

Vertical countermovement jump: The participant stands feet parallel on a contact mat (Newtest Powertimer, Oulu, Finland) and is asked to jump as high as possible. The arms are allowed to swing with the movement. Contact mat records the flight time (seconds) which is converted to centimetres. The countermovement jumps are performed 3 times. The best result is used in analyses.

<u>*Flexibility*</u>

Forward bending (Gauvin et al. 1990): The participant stands in a straddled position and bends the trunk forward with knees straight. Forward bending of the spine in the upright position is measured using a modified fingertip-to-floor method (distance in cm). The distance between the tip of the middle finger and the floor is measured with a tape measure.

Shoulder–neck mobility (Suni et al. 1996): The participant is asked to lift arms to overhead flexion against the wall. The classification is done separately for both hands according to the restrictions of the range of motion with a 3-point scale (0 = severe, 1 = moderate, 2 = no restriction, accordingly in total 0 to 4).

<u>*Basic physical fitness tests*</u>

Musculoskeletal fitness:

Static back extension (Biering-Sørensen 1984, Suni et al. 1996)*:* The participant lies prone with the lower body resting on a bench and crosses the hands behind the neck. The tester is sitting on the participant's ankles to counterbalance the posture. The participant raises the upper body to a horizontal level and holds the position as long as possible for up to 4 minutes.

Step squat with added weights (Suni et al. 1996)*:* At first, the participant is asked to squat with both feet in parallel and with the participant's own body weight. The squatting continues by performing it, in turn, right and left foot ahead in tandem position (step squat), adding 10% of body weight for each squat, up to 40%. Each leg is rated separately, each successful step squat equates one point (0 to 6 points), and the final result is the sum of the points for both legs (maximum 12 points).

Aerobic fitness

2-km walk test (Oja et al. 1991, Laukkanen 1993): The participant performs the 2-km walk test that measures aerobic capacity indirectly. VO_{2max} is predicted by an equation according to time of 2-km walking, heart rate at the end of the test and, in addition, age, gender and BMI.

Appendix 3 Geometric means with minimum and maximum values of the tests that were included in each study are presented as descriptive data of the Studies I, II, III and V. Selected motor performance tests were measured, and in addition, in the Study V physical fitness in terms of aerobic capacity and muscle strength was measured.

Test item	Men				Women	
	Study I	Study II and III		Study V	Study I	Study V
Motor performance	(n=14) Geometric mean (min-max)	TBI (n=34) Geometric mean (min-max)	Control (n=36) Geometric mean (min-max)	(n=69) Geometric mean (min-max)	(n=11) Geometric mean (min-max)	(n=79) Geometric mean (min-max)
Static postural balance						
Standing on a narrow bar, corrective touches, n	5 (0-27)	-	-	5.4 (1-31)	5 (1-10)	9.4 (1-41)
Dynamic postural balance						
Tandem forwards, s	10.4 (6.0-15.5)	14.9 (9.3-28.5)	11.0 (6.3-20.3)	12.1 (7-32)	11.9 (10.0-17.0)	14.5 (8-37)
Tandem backwards,s	11.9 (7.0-17.0)	16.7 (10.0-37.2)	13.4 (9.0-27.0)	13.8 (9-25)	15.9 (12.0-23.5)	16.9 (10-48)
Orientation						
Ball bouncing, 20 throws, s	23.8 (16.0-51.5)	-	-	21.1 (15-45)	29.8 (22.0-55.5)	25.0 (15-60)
Agility/Explosive strength						
Figure-of-eight run, s	-	8.2 (6.2-15.6)	6.5 (5.6-7.6)	7.1 (5.7-11.8)	-	8.2 (6.6-11.3)
Vertical jump height, cm	-	-	-	35.8 (21.0-58.0)	-	23.9 (13.1-35.6)
Flexibility						
Forward bending, cm	0.3 (0.0-24.5)	-	-	0.1 (0.0-50.0)	0.0 (0.0-16.0)	0.0 (0.0-30.0)
Static postural balance						
Standing on one-leg unsuccessful /successful, n	3/11	right 15/19 left 17/17	right 5/31 left 3/34	11/58	2/9	23/56
Rhythm coordination, Inaccurate/Accurate, n						
slow phase	6/8	14/20	5/31	16/53	4/7	30/49
fast phase	2/12	21/13	8/28	21/48	2/9	34/45
Vertical ball throwing, Inaccurate/Accurate, n	0/14	-	-	17/52	1/9	29/50

(continues)

(Appendix 3 continues)

Flexibility, shoulder-neck						
ROM restricted/free, n	-	-	-	28/41	-	26/53
Standing broad jump						
Inaccurate/accurate jump, n	7/7	-	-	32/37	5/6	48/30
Physical fitness						
Static back extension endurance	-	-	-	101.4 (32-240)	-	98.5 (10-240)
Step squat with increasing weights restricted/maximal performance, n	-	-	-	8 /61	-	44/55
2-km walk test	-	-	-			
VO_{2max} (estimated)				37.0 (17.8-54.1)	-	31.3 (10.0-40.2)

ORIGINAL PUBLICATIONS

I

TEST-RETEST REPRODUCIBILITY AND INTER-RATER RELIABILITY OF A MOTOR SKILL TEST BATTERY FOR ADULTS

by

Rinne MB, Pasanen ME, Miilunpalo SI, Oja P. 2001.

International Journal of Sports Medicine 22, 192-200.

II

THE TEST-RETEST RELIABILITY OF MOTOR PERFORMANCE MEASURES AFTER TRAUMATIC BRAIN INJURY

by

Vartiainen MV, Rinne MB, Lehto TM, Pasanen ME, Sarajuuri JM,
Alaranta HT. 2006.

Advances in Physiotherapy 8, 50-59.

III

MOTOR PERFORMANCE IN PHYSICALLY WELL-RECOVERED MEN WITH TRAUMATIC BRAIN INJURY

by

Rinne MB, Pasanen ME, Vartiainen MV, Lehto TM, Sarajuuri JM,
Alaranta HT. 2006.

Journal of Rehabilitation Medicine 38, 224-229.

J Rehabil Med 2006; 38: 224–229

MOTOR PERFORMANCE IN PHYSICALLY WELL-RECOVERED MEN WITH TRAUMATIC BRAIN INJURY

Marjo B. Rinne[1], Matti E. Pasanen[1], Matti V. Vartiainen[2], Tommi M. Lehto[2], Jaana M. Sarajuuri[2] and Hannu T. Alaranta[2]

From the [1]UKK Institute for Health Promotion Research, Tampere and [2]Käpylä Rehabilitation Centre, Helsinki, Finland

Objective: **The primary aim of this study was to compare the motor performance of physically well-recovered men with traumatic brain injury with that of healthy men.**
Design: **Cross-sectional study in a national rehabilitation centre.**
Methods: **Static and dynamic balance, agility and rhythm co-ordination of men with traumatic brain injury ($n = 34$) and healthy controls ($n = 36$) were assessed. Between-group differences in dynamic balance and agility were analysed by analysis of covariance and differences in static balance and rhythm co-ordination by logistic regression analysis. Cut-off points for clinical screening were determined by receiver operating characteristics analyses.**
Results: **Men with traumatic brain injury had impaired balance and agility compared with healthy men and in a rhythm co-ordination test they had difficulties in starting and sustaining simultaneous rhythmical movements of hands and feet. In receiver operating characteristics analyses a running figure-of-eight test (agility), tandem walking forwards (dynamic balance) and rhythm co-ordination test with fast tempo were found the most sensitive and specific for distinguishing between men with traumatic brain injury and the healthy men.**
Conclusions: **The impairments in motor performance of physically well-recovered patients with traumatic brain injury were obvious. The results of this study extend the knowledge of problems in motor performance among patients with traumatic brain injury and provide further information for clinical rehabilitation.**

Key words: brain injury, motor skills, psychomotor performance, rehabilitation.

J Rehabil Med 2006; 38: 224–229

Correspondence address: Marjo Rinne, UKK Institute for Health Promotion Research, PO Box 30, FI-33501 Tampere, Finland. E-mail: marjo.rinne@uta.fi

Submitted June 27, 2005; accepted January 3, 2006

INTRODUCTION

Traumatic brain injury (TBI) is a worldwide public health problem (1). The incidence of hospitalized patients with TBI in the USA has been 618 cases/100,000 person years (py), in Southern Australia 322 cases/100,000 py and in Scotland 326 cases/100,000 py (2–4). According to Sosin et al. (3) only 25% of all TBI cases are treated in hospitals. The number of new hospitalized TBI cases in Finland has been 100/100,000 py (5).

TBI is known to cause a diversity of disorders, involving motor performance, behavioural, emotional and cognitive symptoms. Cognitive and behavioural deficits resulting from TBI have been well documented, but this is not the case for the physical symptoms in terms of moderate or mild TBI. In conventional neurological examinations the findings may often be normal, but the patients still complain of undefined symptoms. These subjectively experienced symptoms may arise when patients are returning to pre-morbid activities, sport or work (6–8).

Impaired balance and altered co-ordination are common complaints (9, 10). From a clinical point of view, many patients with TBI have difficulties in tasks requiring simultaneous rhythmic movements of the upper and lower limbs compared with uninjured counterparts (11). In terms of physical problems after mild or moderate TBI, it has been considered important to identify rapid alternating movements, gait and balance, static/dynamic posture and vestibular system integrity (8).

So far, no widely accepted standardized motor performance screening tests for adult patients with TBI are available for clinical use. Even with the problems in motor performance that are observed clinically, it is not clear how to assess motor performance among physically well-recovered patients with TBI. The primary aim of this study was to compare the motor performance of physically well-recovered men with TBI with a control group of healthy men. The secondary aim was to establish sensitive, specific and valid cut-off values of respective motor performance measures for clinical use.

MATERIAL AND METHODS

Subjects

Voluntary male patients with TBI who consecutively attended a nationwide rehabilitation centre (Käpylä Rehabilitation Centre, Helsinki, Finland) and who fulfilled the inclusion criteria of the study were recruited between March 2001 and March 2002. In total, 41 subjects with TBI were interviewed on the first day of their rehabilitation period to ensure compatibility for the study. Healthy men of similar age and years of education as the subjects with TBI served as controls. The inclusion criteria for all the subjects were: (*i*) age 19–55 years; (*ii*) body mass index (BMI) less than 35; (*iii*) passed Mini Mental State Examination (MMSE; normal >24/30), which is a widely used method for assessing cognitive status in adults, testing orientation, attention, immediate and short-term recall, language, and ability to follow simple verbal and written commands (12); and they were able (*iv*) to maintain initial test positions; (*v*) to perform a 2 km Walk Test developed at UKK Institute (13); and (*vi*) to run a short distance. In addition, for the subjects with TBI, more than one year should have passed since the

 ISSN 1650-1977
DOI: 10.1080/16501970600582989

injury. To determine the eligibility for the study the type and time of the injury were verified from medical files. In addition, Glasgow Coma Scale (GCS) scores (the worst score during the first 24 hours at acute hospital admission) were also re-examined and radiological (computed tomography (CT)/magnetic resonance imaging (MRI)) findings were evaluated by a neurologist from medical files. The subjects were interviewed about the length of post-traumatic amnesia (PTA). Of the patients with TBI, 2 refused to participate in the study and 5 were excluded due to the inclusion criteria. In total, 34 men with TBI (mean age 34 years) and 36 healthy controls (mean age 31 years) met the inclusion criteria. All participants gave their informed consent. A description of subjects is given in Table I. The study was approved by the Ethics Committee for Ophthalmology, Otorhinolaryngology, Neurology and Neurosurgery of the Helsinki and Uusimaa Hospital District.

Test protocol

A pre-test health screening was conducted according to the safety model of the UKK health-related fitness test battery for adults, which included a modified version of the physical activity readiness questionnaire (MPAR-Q) (14) and questions on current and past physical activity.

The test battery consisted of 5 tests: 1 for static balance (14), 2 for dynamic balance (14, 15), figure-of-eight running test for agility (16) and a test for rhythm and co-ordination with slow and fast tempo (15). The tests were carried out in a silent environment, on a flat surface with enough space, at least 15 metres, for moving. All tests were performed with shoes on. Each test session lasted approximately 30 minutes. Subjects were instructed not to smoke 30 minutes before the test session, not to be under the influence of alcohol during testing, and to avoid stimulants, such as coffee, tea, etc., one hour before testing. Before starting, the tester explained and demonstrated the performance of each test and the subjects were allowed to practice it once.

Test procedure

Static and dynamic balance.

Balancing on 1 leg (14). In order to measure static balance subjects stood on 1 leg with their eyes open and arms relaxed by their sides. They placed the heel of the opposite foot against the medial side of the supporting leg at the level of the knee joint, and kept the thigh rotated outwards. Static balance time was measured with a stopwatch in seconds, and the uppermost limit for the trial was 60 seconds. If this limit was not reached during the first trial, a second trial was allowed. The best of 2 trials was used in the statistical analyses. The test was performed separately on both legs, starting on the right leg.

Tandem walking forwards (15). In order to measure dynamic balance, the subjects were instructed to place one foot in front of the other with the heel and toe of their shoes touching (tandem step), and walk as fast as possible along a line 6 metres long without side touches or mistakes in tandem steps. The test was performed 3 times and the walking time of each trial was measured in seconds. The best result of 3 trials was used in the analyses.

Tandem walking backwards (14). The instructions and the conditions were the same as for tandem walking forwards, but the walking direction was backwards. The best result of 3 trials was used in the analyses.

Agility.

Running in a figure-of-eight (16). The subjects were asked to run as fast as possible a course in a figure-of-eight. The course was marked with 2 traffic cones placed 10 metres apart with the start/finish line next to one of the cones, the total length of the course being 20 metres. The stopwatch was started concurrently with the starting signal and was stopped when the subject completed the course and crossed the start/finish line again. The time was recorded in seconds. This test procedure was in line with the original test procedure but in this study subjects were asked to run the course only once in each trial. On the whole, the test was performed 3 times with a short resting period between each trial. The best result of 3 trials was used in the analyses.

Rhythm and co-ordination.

Slow rhythm phase (15). The slow rhythm comprised 2 consecutive parts, each of 30 seconds duration, and the tester scored the

Table I. *Characteristics of subjects with traumatic brain injury (TBI) and control group, mean values with standard deviation (SD) of the performance in tandem walking tests and running in a figure-of-eight and proportion (%) of unsuccessful/successful test performance in balance and rhythm co-ordination tests*

	TBI group ($n=34$)	Control group ($n=36$)
Age (years; mean (SD))	34 (10)	31 (11)
Height (cm; mean (SD))	177 (7)	178 (8)
Weight (kg; mean (SD))	80 (15)	79 (13)
Months since trauma (median)	24	–
Length of education (n)		
9 years	7	6
10 years	1	1
12 years	26	29
Post-traumatic amnesia (n)		
Mild (<24 hours)	1	–
Moderate (1–7 days)	7	–
Severe (>7 days)	10	–
Very severe (>4 weeks)	15	–
Unknown	1	–
Glasgow Coma Scale score*		
Mild (13–15)	10	–
Moderate (9–12)	1	–
Severe (3–8)	15	–
Brain CT/MRI findings (n)		
Contusion and/or intracranial haematoma	26	–
Diffuse axonal injury	5	–
Signs of severe intracranial pressure	4	–
Neurosurgical treatment		
Craniotomy	2	–
Type of rehabilitation after injury (n)		
Outpatient		
Neuropsychological rehabilitation	24	–
Physical therapy	14	–
Speech therapy	3	–
Occupational therapy	4	–
Inpatient rehabilitation	6	–
Subjectively perceived motor deficiencies in sport activities (n)		
Defects in balance	8	–
Clumsiness in arm movements	3	–
Difficulties in running	6	–
Fatigue	6	–
Weekly exercise or sport activities (times)		
None	10	3
Once or twice	6	5
Three times or more	20	25
Weekly leisure time physical activities (times)		
None	1	1
Once or twice	19	13
Three times or more	14	22
2 km Walk Test		
Walking time (minutes:seconds; mean, (SD))	18:49 (2:16)	17:24 (2:00)
Mean performance times of tests (seconds; mean, (SD))		
Tandem walking forwards	14.9 (4.3)	11.3 (2.8)
Range	9.3–28.5	6.3–20.3
Tandem walking backwards	17.6 (6.3)	14.0 (4.3)
Range	10.0–37.2	9.0–27.0
Running in figure-of-eight	8.4 (2.1)	6.6 (0.5)
Range	6.2–15.6	5.6–7.6

Table I (*Continued*)

	TBI group (n = 34)	Control group (n = 36)
Proportion of unsuccessful/successful performance		
Balance on 1 leg (%)	44/56	14/86
On the right leg (<60 seconds/ 60 seconds)		
On the left leg (<60 seconds/ 60 seconds)	50/50	8/92
Rhythm co-ordination (%)		
Slow rhythm (0–6 points/ 7–8 points)	65/35	31/69
Fast rhythm (0–6 points/ 7–8 points)	65/35	28/72

*Glasgow Coma Scale scores were registered at acute hospital phase in 26 patients' medical files; registration was missing in 8 patients files.

performance of each part in points. At the start the subject was asked to march on the spot in accordance with a metronome signal (M = 92 beats/min), one step for every single beat for 30 seconds. After that the subject was asked to continue marching for another 30 seconds and to clap his hands together on every other beat. Points were given for both parts separately according to: (*i*) accuracy in the first 10 seconds: 0 = totally asynchronous marching, 1 = getting in the marching rhythm gradually during the first 10 seconds, 2 = synchronous marching rhythm at first go; and (*ii*) maintenance of the exact rhythm from 10 to 30 seconds: 0 = totally asynchronous rhythm co-ordination while marching and clapping, 1 = difficulties in keeping to the rhythm, 2 = maintaining accurate marching and clapping rhythm for rest of the test. In consequence, the sum of these scores in the slow rhythm phase was 0–8 points, which was used in the analyses.

Fast rhythm phase (15). The fast rhythm phase started immediately after the slow phase when the tester had set the metronome to a fast rhythm (M = 138 beats/min), otherwise the same procedure was repeated to the rhythm of the metronome. The sum of the scores in the fast rhythm phase was also 0–8 points which was used in the analyses.

Both slow and fast rhythm phases were performed only once.

Statistical methods

The means and standard deviations (SD) are presented as descriptive statistics. In the dynamic balance tests and agility test the between-group differences were analysed by analysis of covariance (ANCOVA) adjusted for age. Logistic regression analysis was used for analysing the group differences in static balance and sense of rhythm tests. In the analyses the results of these tests were used as dichotomous dependent variables, the group variable as independent variable and age as covariate. For the analysis the results of the static balance tests were dichotomized into categories of 60 seconds and below 60 seconds. In the rhythm co-ordination tests a dichotomous variable was formed according to the accuracy of the test: "synchronous movements" 7 or 8 points, "asynchronous movements" 0–6 points. Age-adjusted odds ratios (OR) and their 95% confidence intervals (CI) were calculated.

In order to find the abnormalities in motor performance caused by TBI receiver operating characteristics (ROC) analyses were performed. On the basis of the ROC analyses cut-off values were determined and calculated for all tests with their respective sensitivity and specificity to distinguish "normal" from "abnormal" performance. The ROC analysis evaluates the general performance of the measures and describes the clinical performance of screening tests in terms of diagnostic accuracy: The true positive rate (sensitivity) is plotted against the false positive rate (1–specificity). The area under the curve (AUC) in the ROC analysis generally assesses the discriminatory power of the test. The AUC can take values between 0 and 1 where an AUC of 1 is a perfect screening test and 0.5 represents a test equal to chance. In the ROC curve diagrams, a 45° line was plotted representing an AUC of 0.5. The perfect cut-off point is in the upper left corner of the graph. For clinical use the point closest to this was considered to be the optimal cut-off value to minimize misclassifications (17, 18). All statistical analyses were performed using SPSS software, version 12.0.1 (SPSS INC, Chigago IL, USA).

RESULTS

The study population is described in Table I. The subjects in the TBI group were slightly older than the controls (mean age 34 vs 31 years) which was taken into consideration in the analyses. In the TBI group 55% (19 men) had medical treatment for sleeping or mood problems or pain. Only 3 men in the control group had medication, 2 for allergy and one for asthma. No other remarkable between-group differences were seen in the background characteristics. Overall, 79% (24 men) of the TBI group reported that they have had to change their sport activities after injury and 4 men of TBI group had totally quitted their former sport activities. Subjectively experienced deficiencies are presented in more details in Table I.

Static balance was measured by standing both on the right and on the left leg. As the result of logistic regression analysis, the TBI group had poorer static balance than the controls (OR of the right leg for poor performance (below 60 seconds) 4.6, 95% CI 1.4–15.3; OR of the left leg 10.7, 95% CI 2.7–43.6, respectively). Nearly half of the TBI group were unable to maintain their balance on one leg (44% on the right, 50% on the left leg) for 60 seconds. However, only 14% of the controls did not reach the uppermost limit in static balance test on the right leg and 8% on the left leg.

The means and SD of the dynamic balance and agility tests are also shown in Table I. The TBI group performed both 6 metres of tandem walking forwards and backwards statistically significantly more slowly than the control group. The age-adjusted mean differences between the study groups were 3.3 seconds in the tandem walking forwards (95% CI 1.6–4.9; $p = 0.001$; ANCOVA) and 3.2 seconds in walking backwards (95% CI 0.7–5.8; $p = 0.014$). In the agility test the TBI group running a figure-of-eight was statistically significantly slower than in the control group, the mean difference being 1.7 seconds (95% CI 1.0–2.4; $p < 0.001$). In addition, the range of test results was wider among the subjects with TBI than in controls in all tests involving motion.

The age-adjusted OR for arrhythmic (0–6 points in test) co-ordination was 4.3 (95% CI 1.3–13.9) when comparing the TBI group with the controls. In the slow rhythm co-ordination test 41% of the subjects in the TBI group had difficulties in starting or/and maintaining the given rhythm. However, only 14% in control group performed the test inaccurately. At fast rhythm 62% of the men in the TBI group had difficulties with rhythm co-ordination, whereas 22% of the controls had asynchronous performance (OR 7.3; 95% CI 2.3–23.6).

Sensitivity, specificity, cut-off points and the AUC for each test are given in Table II. The ROC curves for the both tandem

Table II. *Receiver operating characteristic (ROC) curve areas and cut-off points for tandem walking forwards and backwards, agility, balancing on one leg and rhythm co-ordination tests with their respective sensitivity and specificity to distinguish men with traumatic brain injury (TBI) from healthy subjects*

Test	Area under curve (95% CI)	Cut-off point	Sensitivity (%)	Specificity (%)
Tandem walking forwards	0.76 (0.65–0.88)	≥13.0 seconds	70.6	77.8
Tandem walking backwards	0.70 (0.57–0.82)	≥16.0 seconds	55.9	77.8
Running in figure-of-eight	0.86 (0.78–0.95)	≥7.2 seconds	73.5	86.1
Balancing on 1 leg (max. 60 seconds)				
On the right leg	0.65 (0.52–0.78)	≤59 seconds	44.1	86.1
On the left leg	0.71 (0.59–0.84)	≤55 seconds	50.0	91.7
Rhythm co-ordination (max. 8 points)				
Slow rhythm	0.70 (0.57–0.82)	≤7 points	64.7	69.4
Fast rhythm	0.75 (0.63–0.86)	≤6 points	61.8	77.8

Area under curve reflects the probability that a random person with TBI has a higher value of measurement than a random person without TBI. The optimal cut-off point for identifying the TBI patients. Sensitivity: true positive rate. Specificity: 1-false positive rate.

walking tests and running the figure-of-eight test are presented in Fig. 1A, for balancing on one leg in Fig. 1B and rhythm co-ordination in Fig. 1C. In the agility test (running the figure-of-eight) 56% of the men in the TBI group performed the test more slowly than the controls. The probability of detecting problems in motor performance caused by TBI was best in this test; the AUC value was the highest at 0.86. Accordingly, the determined cut-off point of 7.2 seconds had the highest sensitivity and specificity of all tests used in this study, 74% and 86%, respectively.

The AUC values in other motor performance tests were fairly high, varying from 0.70 to 0.76, except in the balancing test on the right leg. Of dynamic balance tests the tandem walking forwards and the test for fast rhythm also had good sensitivity and specificity.

DISCUSSION

In the present study we assessed the motor performance of the physically well-recovered men with TBI in terms of agility, balance and rhythm co-ordination, which was clearly impaired compared with the control group. The subjects with TBI performed the figure-of-eight running and tandem walking tests statistically significantly more slowly than the control group and had difficulties in co-ordinating simultaneous hand and foot movements in a given rhythm. Due to these differences the ROC curves and cut-off values with their respective sensitivity and specificity proved to be relevant.

These deficits may be partly explained by reduced velocity due to TBI. Basford et al. (10) performed a three-dimensional motion analysis of self-selected walking speed and balance among patients with TBI and healthy subjects. The patients with TBI were found to have significantly lower body centre of mass displacement and velocities in anterior–posterior direction than the healthy controls, whereas the mediolateral movements were larger, both reflecting reduced walking velocity. In our study the patients with TBI had also difficulties in maintaining static balance both on the right and left leg, some of them could stand only a few seconds on one leg. These findings are in line with the study by Geurts et al. (19), where they observed patients with TBI standing quietly on both feet and a weight shifting task on a dual-plate force platform.

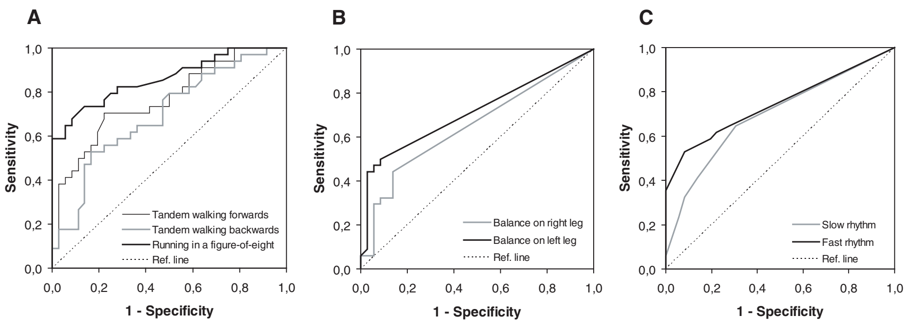


Fig. 1. Receiver operating characteristic (ROC) curve analyses of sensitivity and specificity for determining the optimal cut-off point to distinguish "normal" performance from "abnormal". (A) Tandem walking forwards, tandem walking backwards and figure-of-eight running tests. (B) Balancing on the right leg and on the left leg tests. (C) Slow and fast rhythm co-ordination tests. The broken line represents a test equal to chance (area under curve = 0.5). All the performance tests distinguished the men with TBI from the healthy men statistically significantly better than by chance ($p < 0.05$).

Furthermore, in our study, simultaneous marching and hand clapping to a given rhythm proved to be a more difficult task for patients with TBI than the controls. The subjects had difficulties while performing the slow rhythm, but the fast rhythm co-ordination task revealed even more problems compared with the healthy controls. Our results were consistent with those reported by Azouvi et al. (11), who described slowed information processing in dual-tasks test and even more difficulties in a high time-pressure in laboratory setting.

Because the differences between the TBI and control groups were statistically significant, it was important to determine the cut-off points with the best sensitivity and specificity for clinical use. The figure-of-eight running, fast rhythm co-ordination and tandem walking forwards tests were the best for screening out men with TBI from healthy controls. In the same way, the specificity of the static balance test was high, but sensitivity remained low due to the ceiling effect of the uppermost limit of 60 seconds: most of the controls were able to stand on one leg for the whole minute.

In rhythm co-ordination the first analyses of differences between the groups was based on an assessment used earlier among healthy middle-aged men and women (15). In this study the cut-off points were determined more precisely for clinical use according to the ROC analyses, which gives a more exact evaluation. In the fast phase rhythm co-ordination 6 points became the cut-off having higher sensitivity and specificity than cut-off at 7 points, which is used in logistic regression analysis. However, the between-group differences both in slow and fast rhythm were already found at 7 points.

The motor performance items, which were the objects of our study, were also listed as items of the most obvious problems resulting from TBI and considered to be included for formal assessment (8). Moreover, it is probable that similar diffuse deficiencies in motor performance may be observed in patients with other diagnoses than TBI, e.g. patients with different types of stroke or patients using drugs affecting motor performance. In our study the subjects with TBI described their subjectively perceived of motor deficiencies as defects in balance, difficulties in running, clumsiness in arm movements and fatigue. The results of static and dynamic balance, figure-of-eight run and rhythm tests were in accordance with those descriptions, even though the gross motor clinical neurological examinations had not revealed the deficiencies. Even if the need for knowledge and tests measuring motor performance of physically well-recovered patients with TBI is recognized, only a few earlier studies have been aiming to explore these aspects (10). The tests used in this study are easy to administer in a clinical environment and constitute a test battery measuring different aspects of motor performance.

However, it should be noted that this study was conducted among men, and generalization to women concerning assessment of motor performance should be made with caution. In general, men are at greater risk of even mild TBI, the risk for men being 0.88–2.5 times higher than the risk for women (1, 20). In our study, the men with TBI were, on admission to acute hospitals after the accident, rather heterogeneous with respect to a large variation of GCS scores (range 3–15) and different types of CT/MRI findings. After the acute phase, most of the TBI subjects had also been in outpatient rehabilitation. When the TBI subjects attended to Käpylä Rehalitation Centre and participate to this study, at least one year had passed since the injury. On whole, the TBI subjects seemed to be recovered physically well and were consistent with the inclusion criteria, but the representativeness of the results is limited due to small sample size. Nevertheless, the number of subjects was sufficient for reliable statistical analyses and the results can be interpreted indicatively.

In conclusion, the results established that deficiencies in the motor performance of physically well-recovered patients with TBI disturbing pre-morbid activities can be detected in clinical practice. The usefulness and validity of the test battery should be investigated in larger prospective studies. Further research is needed to compare different subgroups of TBI patients, in order to determine and to evaluate the precise effects of TBI rehabilitation on motor performance.

ACKNOWLEDGEMENTS

A poster presentation at the 5th World Congress on Brain Injury in Stockholm in 2003, was partly based on the present data. This study was supported by Finnish Ministry of Education Grant No 196/722/2000. We thank Jukka Turkka, MD, PhD, who ensured injury-related variables. The researchers also express their gratitude to all participants.

REFERENCES

1. Cassidy JD, Carroll LJ, Peloso PM, Borg J, von Holst H, Holm L, et al. WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehabil Med 2004; (suppl 43): 28–60.
2. McGuire SA, Gronseth GS, Adams A. Incidence of traumatic head injury in a defined population. Neurology 1995; 45(suppl 4): A328.
3. Sosin DM, Sniezek JE, Thurman DJ. Incidence of mild and moderate brain injury in the United States, 1991. Brain Inj 1996; 10: 47–54.
4. Hillier SL, Hiller JE, Metzer J. Epidemiology of traumatic brain injury in South Australia. Brain Inj 1997; 11: 649–659.
5. Alaranta H, Koskinen S, Leppänen L, Palomäki H. Nationwide epidemiology of hospitalized patients with first-time traumatic brain injury with special reference to prevention. Wien Med Wschr 2000; 150: 444–448.
6. Dombovy M, Olek A. Recovery and rehabilitation following traumatic brain injury. Brain Inj 1996; 11: 305–318.
7. Masanic C, Bayley M. Interrater reliability of neurologic soft signs in an acquired brain injury population. Arch Phys Med Rehabil 1998; 79: 811–815.
8. Quinn B, Sullivan J. The indentification by physiotherapists of the physical problems resulting from a mild traumatic brain injury. Brain Inj 2000; 14: 1063–1076.
9. Newton RA. Balance abilities in individuals with moderate and severe traumatic brain injury. Brain Inj 1995; 9: 445–451.
10. Basford JR, Chou L-S, Kaufman KR, Brey RH, Walker A, Malec AM, et al. An assessment of gait and balance deficits after traumatic brain injury. Arch Phys Med Rehab 2003; 84: 343–349.
11. Azouvi P, Couillet J, Leclerq M, Martin Y, Asloun S, Rousseaux M. Divided attention and mental effort after severe traumatic brain injury. Neuropsychologia 2004; 42: 1260–1268.

12. Folstein MF, Folstein SE, McHugh PR. Mini Mental State. A practical method for grading the cognitive state of patients for clinician. J Physiatr Res 1975; 12: 189–198.
13. Laukkanen R. Development and evaluation of a 2-km walking test for assessing maximal aerobic power of adults in field conditions [Doctoral Dissertation]. Kuopio University Publications D. Medical Sciences 23; 1993.
14. Suni JH, Miilunpalo S, Asikainen T-M, Laukkanen RT, Oja P, Pasanen M, et al. Safety and feasibility of a health-related fitness test battery for adults. Phys Ther 1998; 78: 134–148.
15. Rinne MB, Pasanen ME, Miilunpalo SI, Oja P. Test-retest reproducibility and inter-retaer reliability of a motor skill test battery for adults. Int J Sports Med 2001; 22: 192–200.
16. Tegner Y, Lysholm J, Lysholm M, Gillquist J. A performance test of monitor rehabilitation and evaluate ACL-injuries. Am J Sports Med 1986; 14: 156–159.
17. Feinstein AR. Clinical epidemiology: the architecture of clinical research. Philadelphia: WB Saunders Co; 1985.
18. Armitage P, Berry G, Matthews JNS. Statistical methods in medical research, 4th edn. Oxford: Blackwell Science; 2002.
19. Geurts AC, Ribbers GM, Knoop JA, van Limbeek J. Identification of static and dynamic postural instability following traumatic brain injury. Arch Phys Med Rehabil 1996; 77: 639–644.
20. Peloso PM, von Holst H, Borg J. Mild traumatic brain injuries presenting to Swedish hospitals in 1987–2000. J Rehab Med 1987; (suppl 43): 22–27.

IV

EVALUATION OF REQUIRED MOTOR ABILITIES IN COMMONLY PRACTISED EXERCISE MODES AND POTENTIAL TRAINING EFFECTS AMONG ADULTS

by

Rinne MB, Miilunpalo SI, Heinonen AO. 2007.

Journal of Physical Activity and Health 4, 203-214.

Journal of Physical Activity and Health, 2007, **4**, 203-214

Evaluation of Required Motor Abilities in Commonly Practiced Exercise Modes and Potential Training Effects Among Adults

Marjo B. Rinne, Seppo I. Miilunpalo, and Ari O. Heinonen

Background: There is a lack of knowledge of the motor abilities required in different exercise modes which are needed when counseling sedentary middle-aged people to start a physically active lifestyle. *Methods:* Nominal group technique was used to establish the consensus statement concerning motor abilities and physical fitness in 31 exercise modes. *Results:* Walking, running, jogging, and calisthenics were regarded as the most suitable exercise modes for most people with no specific requirements. The most demanding exercise modes of evaluated exercise modes were roller skating, downhill skiing, and martial arts, requiring all five motor abilities. Four abilities were necessary in skating, jazz dance, and ice hockey. When exercising is target-oriented, endurance is trained evidently in 27 out of 31 and muscle strength in 22 out of 31 exercise modes. *Conclusions:* The consensus statement gives theoretical basis for the components of motor abilities and physical fitness components in different exercise modes. The statement is instructive in order to promote health-enhancing physical activity among sedentary people. This study completes the selection of the exercise modes more detailed than current PA recommendation and guidelines for public health. A variety of exercise modes with one or none motor requirements is available to start. When amount and intensity of exercise is increased the training effects can be found in most components of motor ability and physical fitness.

Key Words: health-related physical activity, sedentary middle-aged, counseling, nominal group

Basic motor abilities are necessary for daily physical activities (PAs). They consist of separate characteristics such as orientation, kinaesthetic differentiation, balance, sense of rhythm, and reaction ability. In addition, definitions such as multilimb coordination, control precision, timing, and aiming have been widely used.[1-5] Motor abilities and skills are developed during maturation but PA has been shown to be very important in improving or maintaining motor abilities during adulthood. On

Rinne is with the UKK Institute for Health Promotion Research, Tampere, Finland. Miilunpalo is with the Kiipula Centre of Vocational Education and Rehabilitation, Turenki, Finland. Heinonen is with the Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland.

the other hand, inactivity, aging, and health problems may impair these abilities. Aside from motor abilities, a certain level of physical fitness consisting of aerobic endurance, muscle strength, flexibility, and agility, is needed to participate in daily PAs or different exercise modes.[5]

PA in various exercise modes is recommended to improve health and fitness and mostly the focus has been on frequency, duration, and intensity of exercise.[6-8] To achieve health and fitness benefits, it is important to find appropriate exercise modes. Starting and maintaining a physically active lifestyle in adulthood depends much on successful experiences in practice. From this point of view, motor abilities and skills in different exercise modes are fundamentally more important than physical fitness.

As far as we know, there is little systematic information on motor abilities required in the exercise modes practiced by ordinary middle-aged adults. In general, motor ability requirements of different PAs and exercise modes range from basic movements to complex adaptive skills and different characteristics of physical fitness are also necessary to perform specific exercise modes.[5] To date, biomechanical and movement analyses have mostly focused on highly competitive sports for coaching purposes, adapted physical education, and on details of basic locomotion for rehabilitation purposes. Although the theoretical framework for motor abilities exists, the requirements of motor abilities in different exercise modes have not been systematically evaluated. A comprehensive knowledge of these requirements would be beneficial to promote regular PA among physically inactive individuals.

The purpose of this study was to generate a systematic evaluation of the motor abilities and physical performance capacity needed in various exercise modes commonly practiced by middle-aged adults. Accordingly, the final aim was to achieve a consensus statement of these exercise modes according to the type and number of motor abilities needed to participate successfully in different PAs and exercise modes.

Methods

The evaluation of the requirements of the motor ability and physical fitness components in different exercise modes was conducted by nominal group (NG) technique. This technique aims to form an expert group consensus about a given issue when research evidence is lacking.[9-13] The NG method was applied as presented by Jones.[10] The protocol consists of five phases: 1) definition of items, 2) selection of experts, 3) first round of NG meeting, 4) second round of NG meeting, and 5) summary of results for final agreement.

Definition of Items

The definitions of the motor abilities in the present study are given in Table 1. For generation and categorizations the facilitator (MBR) compiled an overview of definitions of the components of motor abilities and physical fitness to provide common background material for the NG panelists in the first round meeting.[1,3] The overview was distributed to the NG panelists when they were invited to the first round meeting. The selection of exercise modes for the first ranking round was based on the PA diaries of sedentary middle-aged men and women (n = 98) who were recruited from our earlier population survey.[14] These subjects were asked to keep PA diaries for a period of 24 wk during winter, spring, summer, and autumn in order to increase their physical activities.

Table 1 The Definition of Motor Abilities (Magill 2004)

Motor ability	Definition
Orientation	to sense posture and movement in relation to space and timing to co-ordinate these in an appropriate way
Kinaesthetic differentiation	to process the auditory, visual and tactile information to anticipate and to control the muscles in relation to each other to needed strength, distance and timing
Balance (static/ dynamic)	to maintain and obtain equilibrium in different postures and movements and centre of gravity over base of support
Reaction ability	the time from the onset of the signal to the completion of a response, includes reaction and movement times
Sense of rhythm	the use of timing and co-ordination influence movement and performance

Selection of Nominal Group Panel

Eight panelists with expertise in promoting physical activity (two men, six women) were invited to join the NG panel. Five of them had an MSc degree and one a PhD in sport science and two an MSc degree in health science. All had practical experience (10 to 15 y) in the fields of physical education, coaching, exercise testing and giving instructions, health counseling, and research work in these topics. In addition, four had been former elite athletes and the others had engaged actively in various modes of PA.

The First and Second Rounds of the NG Panel and the Final Statement

At the beginning of the first round, the facilitator explained the purpose of the NG. First, the panelists and the facilitator discussed the definition of motor abilities and physical fitness components according to the overview distributed in advance. Subsequently, the panelists were asked to rank each selected exercise mode according to the motor abilities and physical fitness required of middle-aged, sedentary people in order to start exercising. The NG panelists evaluated given five motor abilities and four physical fitness components in each exercise mode using a ranking score: 0 = *not required*, 1 = *required to some extent*, 2 = *required to a large extent*, and

3 = *indispensable*. In addition, each mode was ranked according to the assumed training effect on motor abilities and physical fitness in terms of target-oriented exercise. Every item was ranked using a score: 0 = *no training effect*, 1 = *some training effect*, 2 = *moderate training effect*, and 3 = *remarkable training effect*. In total, the maximum points for each component of motor ability and physical fitness were 24 points. In addition, for five motor abilities maximum points were 120 points and for four physical fitness 96 points. Each panelist did the ranking individually and independently but was allowed to make enquiries of the facilitator when necessary.

At the beginning of the second NG round, the facilitator gave a presentation of the results of the first round ranking, which was followed by a general discussion about agreements. After that the panelists had an opportunity to re-rank selected exercise modes if they felt that the new ranking would be more appropriate. Overall, the purpose was to achieve a uniform agreement after two separate rounds and to arrive at the final consensus statement. Both NG sessions lasted for 2 h and all the invited members participated in both sessions.

Data Analysis

The data of the first NG round were analyzed using summary statistics as recommended by Jones.[10] SPSS version 11.0 for Windows (SPSS, Inc., Chicago, IL) was used to calculate the total points for every component of five motor abilities and four physical fitness and subsequently the mean, median, and mode from these total points for each item. The criteria for an exercise mode to be included to the second NG round and also for the cut-off point for high agreement were that the median, mean, and mode of each ranked exercise were ≥ 2 points in the first ranking round.

After the second NG round the total points given (maximum 24 points) for each ability included in the final statement was counted. In addition, all the given points of five motor abilities and physical fitness for each exercise mode were summed (maximum 120 points) to obtain the total requirements.

Results

The final statement of rankings of the exercise modes is given in Tables 2 and 3. Table 2 presents the ratings of assumed requirements and Table 3 shows the ratings of assumed training effects.

After the first NG round, the NG panelists achieved high agreement in 22 out of 31 exercise modes concerning the required motor abilities. With reference to training effects on motor abilities, there was only one disagreement on the effectiveness of training (i.e., balance in calisthenics).

The NG group panelists estimated that roller skating, downhill skiing, and martial arts are the most demanding exercise modes in terms of motor abilities, requiring all five abilities (Table 2). Four abilities were ranked in skating, jazz dance, and ice hockey. In eight exercise modes at least three abilities were required: cross-country skiing, dance, badminton, table tennis, squash, floor ball, and volleyball but only two out of five motor abilities were ranked in aerobics, bowling, golf, basketball, track and field, archery, swimming, cycling, canoeing, and weight training (Table 2).

Table 2 The Required Motor Abilities in Different Exercise Modes Based on the Final Ranking of the Nominal Group Panellists (*n* = 8)

Exercise mode	Motor abilities required					
	Orientation	Kinaesthetic differentiation	Reaction ability	Sense of rhythm	Balance	Σ
5 abilities						
Roller skating	16	19	10*	16	19	80
Downhill skiing	16	17	13	14	15	75
Martial arts	15	14	13	11	13	66
4 abilities						
Jazz dance	18	17		17	13	65
Skating		18	10*	16	19	63
Ice hockey	16	15	13		13	57
3 abilities						
Cross country skiing	13*	14		14		41
Dance	15		14	16		45
Badminton		14	14		13	41
Table tennis		16	16		12*	44
Tennis		17	12*		15	44
Squash		16	14		14	44
Floor ball	13*	13*	13*			39
Volleyball	17	16	14			47
2 abilities						
Aerobics	16			14		30
Bowling				11*	12	23
Golf	13*	15				28
Basketball		14		10*		24
Track and field	18	17				35
Archery	14	15				29
1 ability						
Cycling					17	17
Swimming				11*		11
Weight training		14				14
Canoeing					13	13
None						
Walking						
Running						
Jogging						
Rowing						
Orienteering						
Calisthenics						
Lifestyle physical activity						

The exercise modes are arranged according to the number of abilities required. The sum for each ability (maximum 24) and their total points are presented. * indicates a mode included in the final ranking after voting.

Table 3 The Training Effects on Motor Abilities and Physical Fitness Components in Different Exercise Modes Based on the Final Ranking of the Nominal Group Panelists (n = 8)

Exercise mode	To train motor abilities						To train physical fitness				
	Orientation	Kinaesthetic differentiation	Reaction ability	Sense of rhythm	Balance	Σ	Agility	Endurance	Strength	Flexibility	Σ
Track and field	23	24	22	24	22	115	23	23	22	19	87
Squash	22	23	23	17	22	107	18	19	14		51
Basketball	22	21	20	19	17	99	16	17	13		46
Badminton	21	22	23	14	18	98	15	18			33
Table tennis	19	21	22	19	17	98	17	17			34
Tennis	20	21	20	18	18	97	14	16	14		44
Downhill skiing	21	20	17	18	21	97	14	12	14		40
Ice hockey	21	21	20	16	20	98	18	19	16		53
Volleyball	21	20	19	17	18	95	14	13	13		40
Dance	18	19	13	24	20	94		16			16
Martial arts	20	19	18	15	19	91	16		15	18	49
Floor ball	19	17	18	14	16	84	17	20			37
Roller skating	16	16	11	16	20	79		18	13		31
Skating	14	17	11	16	20	78		18	14		32
Jazz dance	20	22		23	19	84		19	16	22	57
Aerobics	20	19		20	17	76		21	16	15	52
Calisthenics	16	18		17	15*	66		14	15	16	45
Archery	15	17		13	15	60			13		13

Exercise mode	To train motor abilities						To train physical fitness				
	Orientation	Kinaesthetic differentiation	Reaction ability	Sense of rhythm	Balance	Σ	Agility	Endurance	Strength	Flexibility	Σ
Skiing	14	13		16	16	59		22	16		38
Canoeing	14	14		15	16	59		18	17		35
Golf	14	18		16		48					
Orienteering	16				16	32		23			23
Bowling		17		14		31					
Weight training		17				17			24		24
Cycling					13	13		19	15		34
Swimming				13		13		17	12		29
Running							12	23	12		47
Rowing								20	17		37
Jogging								12			12
Walking								15			15
Lifestyle physical activity								10	10		20

The modes which train different components most are listed at the top. The exercise modes are arranged according to the number of abilities required and the points for each ability are presented. The sum of points given for each ability (maximum 24) in the final ranking is presented. * indicates a mode included in the second round after voting.

Kinaesthetic differentiation was considered to be necessary in 58% of the studied exercise modes (*n* = 18). Orientation was required in 14 modes (45%) and balance in 13 modes (42%). In addition, in six exercise modes both orientation and balance were ranked: roller skating, downhill skiing, martial arts, jazz dance, squash, and ice hockey. A sense of rhythm was considered important in all exercise modes with music and in particular, in skating, roller skating, and downhill skiing. In the second round, the panelists voted to add a sense of rhythm as a required motor ability in bowling and basketball (Table 2).

According to the NG group ranking most of the exercise modes seem to have a good training effect on motor abilities. Overall, 14 exercise modes (45%) were considered to have a training effect in order to improve all five motor abilities and six exercise modes (19%) to improve at least four abilities (Table 3). The experts stated that almost all the exercise modes trained some of the motor abilities. However, walking, running, jogging, orienteering, calisthenics, and ordinary PA were considered to have no training effect on motor abilities. Dancing and track and field were the best to improve the sense of rhythm. In addition, track and field received the highest sum (115/120 points) in all five motor abilities.

The NG panelists considered physical fitness necessary in only two of the exercise modes: flexibility was needed in jazz dance and endurance in running. When exercising is systematic and target-oriented, the NG panelists agreed that endurance is trained well in 27 exercise modes. On the whole, 22 out of 31 ranked exercise modes had a training effect on muscle strength. All the ball games were conducive to agility and endurance training. Flexibility training was ranked only in calisthenics, aerobics, jazz dance, martial arts, and in track and field.

As an example, an overview of the training effects of 11 selected exercise modes in relation to motor abilities and physical fitness components are shown as percentages in Figure 1. These percentages indicate in relative terms how effective selected modes are in relation to training motor abilities and physical fitness. The total score is the sum of points given to all components in the first nominal group session (for five motor abilities maximum 120 points and for four physical fitness maximum 96 points). Eight modes for which total sums of all five motor abilities were more than 80% of maximum points were included. These modes seemed to be the best to train motor abilities but they also had good training effects in parallel on physical fitness components. However, walking, cycling, and running were included in this overview even though the percentage values were not high. These exercise modes were the only modes which had training effects more on physical fitness than on motor abilities.

Discussion

The aim of this study was to systematically evaluate the motor abilities and physical fitness components of those exercise modes which middle-aged people most commonly practice. The consensus statement elicited a new approach which can be used as a tool to find suitable exercise modes for beginners and more trained middle-aged individuals to enable them to start a more physically active lifestyle. The NG panelists considered walking, biking, swimming, and jogging to be basic daily PAs which, generally speaking, are the most commonly practiced exercise modes with many positive benefits for health. For instance, walking has low risks

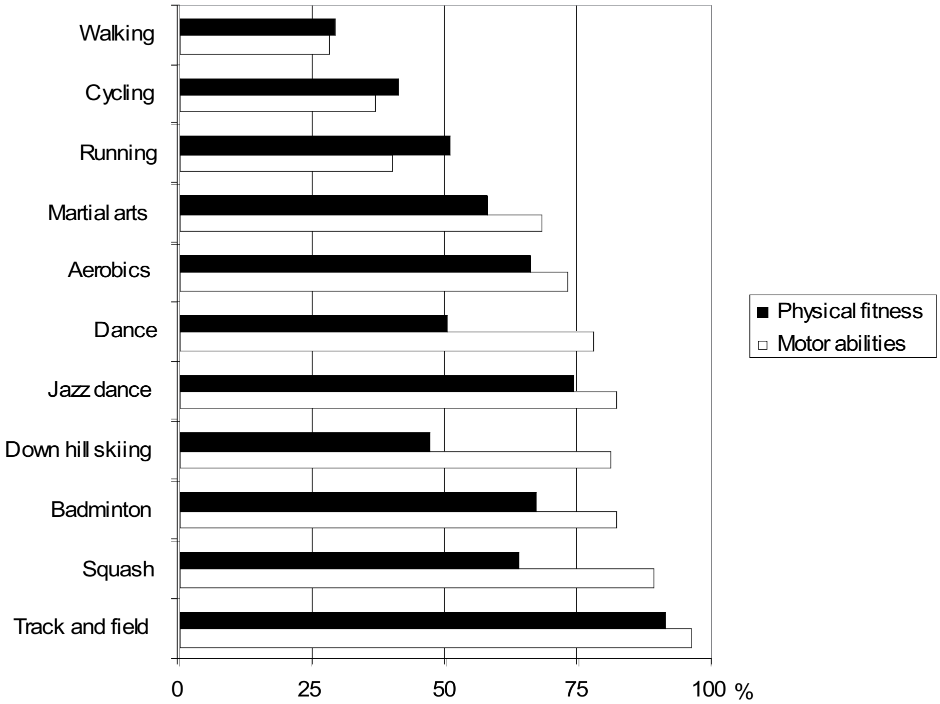


Figure 1—The histograms represent the percentages of training effects both on components of motor ability and physical fitness of 11/31 evaluated exercise modes. Walking, cycling, and running seem to train more physical fitness than components of motor ability. Although the other exercise modes have favorable effects on physical fitness, the components of motor abilities are trained to a greater extent.

and is recommended for sedentary people in order to increase physical activity and improve health and fitness. [6-8,15,16] On the other hand, the panelists considered roller skating, downhill skiing, and martial arts to require all the five motor abilities and for this reason they might not be the preferred exercise modes for beginners.

The most common motor ability seemed to be kinaesthetic differentiation in terms of exercise requirements. According to the definition (Table 1), this ability consists of processing auditory, visual, and tactile information to anticipate and control the muscles in relation to needed strength, distance, and timing. However, balance and orientation were present in 13 exercise modes. This indicates that combinations and modifications of different motor abilities are needed to control movements. A sense of rhythm was clearly indicated in all exercise modes involving music.

The motor ability requirements of schoolchildren have been studied to some extent in terms of physical education. Hirtz[3] reviewed studies on volleyball, basketball, track and field, swimming, and martial arts. The findings were consistent with the NG statement in this study. The requirements in these exercise modes were all the same as in the rankings by the NG panelists. In addition, in our study the sense of rhythm was found to be required in basketball and martial arts, whereas according to Hirtz[3] track and field requires a sense of rhythm. Ainsworth[17] takes a different approach, classifying PAs in terms of metabolic equivalent (MET) intensity level. METs of 3 to 6 have been considered to indicate moderate intensity activity and METs > 6 vigorous intensity. However, the exercise modes in our study are among the physical activities that Ainsworth[17] listed and are consistent with the training effects of physical abilities (Table 3). Activities in our study which have more training effect on physical abilities also have higher METs in Ainsworth's[17] compendium.

The types of exercise modes listed on the ranking form were based on the PA diaries kept by middle-aged men and women in our earlier study.[14] Due to a huge variety of different exercise modes and their connections with cultural and environmental circumstances, such as fashion, settings, equipment, and natural conditions (e.g., snow, water), modes included in the ranking list were comprehensive enough in this context and therefore the selection was not extended. Furthermore, the list of exercise modes in the present study is in line with a previous study involving 3345 Finnish men and women.[18]

The members in the nominal group ranked similarly most of the characteristics of the exercise modes even in the first round of evaluation. The results of the first ranking were mainly concordant, however, but in order to find consensus the group voted on 12 modes out of the 31 exercise modes to be included in the consensus statement. In roller skating, NG members voted on the inclusion of reaction ability and also the inclusion of a sense of rhythm was considered in swimming, bowling, and basketball. The most remarkable change was made in floor ball which had no motor requirements in the first ranking. After discussion in the second round, the panelists added three motor requirements: orientation, kinaesthetic differentiation, and reaction ability. Concerning the training, the panelists had a unanimous opinion; it follows therefore that the agreement was high. The evaluation of training effects was easier because the physical requirements had traditionally been evaluated more frequently and the NG panelists were more familiar with the physical than with the motor requirements.

It should be noted that NG panel selection is critical. According to Jones,[10] participants should have wide experience but a "different mixture" of knowledge on the matter under discussion. Although the nominal group members in this study had the same kind of education, they had long and diverse work histories in different tasks with physical education, exercise testing, rehabilitation, research, and coaching. Some had even been active athletes. This variety of backgrounds provided alternative perspectives and evoked multiprofessional views on the statement.

The nominal group size is usually 5 to 12 participants.[9,10] In this nominal group, there were 8 panelists which was an appropriate size so that all the panelists had an opportunity to participate and to make a final consensus statement. The validity of the NG statement has also been studied. Vella[12] tested the representativeness of the views of NG panelists by a survey in a larger setting and found that the views can represent the conception of the wider community from which they are drawn. However, Jones[10] points out that consensus methods aim to determine the agreement of a group about a given issue. The consensus statement can therefore be considered primarily as a qualitative estimate and the results should be confirmed in observational or experimental studies.

In the present study, the results were analyzed using the recommended descriptive summary statistical methods. In earlier studies, the ranking has been on a 9-point scale but it can be formed into three or four classes.[10] When the scale is reduced, the interpretation is easier because the outermost limits are reduced. In this study, the panelists considered classification into four classes adequate and precise enough for the ranking. Median values have been regarded as an appropriate way to present the data when the first round feedback is given in the second round and even to final statistical summarizing.[9,10,12]

To conclude, this nominal group statement forms a theoretical basis for the most important components of motor abilities and physical fitness considered when engaging sedentary adults in regular PA. These findings can be used in PA counseling of this population in selecting appropriate exercise modes. In the first place, this study is instructive to those who are promoting health-enhancing PA among sedentary people and specifies which exercise modes are easy to start but without high motor demands. Second, this statement completes the selection of the exercise modes which is more detailed than current PA recommendations and guidelines for public health[6,7] and expands the exercise menu of the recent graphically presented Physical Activity Pie.[8]

When adopting PA behavior, inactive people should be counseled to start with exercise modes with one or no motor requirements (see Table 2). Typically, the frequency and intensity of exercise and duration of each session are often determined in PA prescriptions.[15,16] However, the options of different exercise modes are less commonly advised.[6] According to this NG consensus statement, a wide variety of less demanding and safe exercise modes is available to sedentary middle-aged people to start a more physically active lifestyle. The amount and intensity of exercise can be gradually increased and, as a result, both motor abilities and physical fitness components are trained (Table 3) and the improved performance capacity enables participants to select from a wider variety of exercise modes.

A further study to test and clarify the results of this evaluation against observed data will be necessary and to obtain more supporting evidence of the requirements of different exercise modes.

Acknowledgments

The authors express their gratitude to the members of the nominal group.

References

1. Fleishman EA. *The Structure and Measurement of Physical Fitness.* Englewood Cliffs, NJ: Prentice-Hall, Inc.; 1964.
2. Fleishman EA, Quaintance MK. *Taxonomies of Human Performance. The Description Of Human Tasks.* New York: Academic Press; 1984.
3. Hirtz P. *Die Koordinative Fähigkeiten in Schulsport. Vielseitig-variationsreich-ungewohnt.* Berlin: Volk und Wissen Volkseigener Verlag; 1985.
4. Burton AW, Rodgerson RW. New perspectives and the assessment of movement skills and motor abilities. *Adapted Phys Activity Q.* 2001;18:347-365.
5. Magill RA. *Motor Learning and Control. Concepts and Applications.* 7th ed. New York: McGraw-Hill, Inc.; 2004.
6. US Dept of Health and Human Services. Physical Activity and Health: A Report of the Surgeon General. Atlanta: Centers for Disease Control and Prevention (CDC), National Center for Chronic Disease Prevention and Health Promotion, 1996.
7. US Dept of Health and Human Services. *Healthy People 2010.* Accessed October 2002 at: www.health.gov/healthypeople/document/html/volume2/22physical.htm.

8. Fogelholm M, Suni J, Rinne M, Oja P, Vuori I. Physical activity pie: a graphical presentation integrating recommendations for fitness and health. *J Phys Activity Health.* 2005;3:391-396.
9. Green LW, Kreuter MW. *Health promotion planning: an educational and environmental approach.* Mountain View, CA: Mayfield; 1991.
10. Jones J, Hunter D. Consensus methods for medical and health services research. *BMJ.* 1995;311(7001):376-380.
11. Streiner DL, Norman GR. *Health measurement scales: A practical guide. Their development and use.* 2nd ed. Oxford: Oxford University Press; 1995.
12. Vella K, Goldfrad C, Rowan K, Bion J, Black N. Use of consensus development to establish national research priorities in critical care. *BMJ.* 2000;320:976-980.
13. Bartlett DJ, Palisano RJ. Physical therapist's perceptions of factors influencing the acquisition of motor abilities of children with cerebral palsy: Implications for clinical reasoning. *Phys Ther.* 2002;82:237-248.
14. Miilunpalo S, Nupponen R, Laitakari J, Marttila J, Paronen O. Stages of change in two modes of health-enhancing physical activity: methodological aspects and promotional implications. *Health Educ Res.* 2000;4;435-448.
15. Duncan GE, Anton SD, Sydeman SJ, Newton RL Jr, Corsica JA, Durning PE, Ketterson TU, Martin AD, Limacher MC, Perri MG. Prescribing exercise at varied levels of intensity and frequency: a randomized trial. *Arch Intern Med.* 2005;165:2362-2369.
16. Asikainen T-M, Suni JH, Pasanen ME, Oja P, Rinne MB, Miilunpalo SI, Nygård C-H, Vuori I. Effect of brisk walking in 1 or 2 daily bouts and moderate resistance training on lower-extremity muscle strength, balance, and walking performance in women who recently went through menopause: a randomized, controlled trial. *Phys Ther.* 2006;86:912-923.
17. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O'Brien WL, Bassett DR Jr, Schmitz KH, Emplaincourt PO, Jacobs DR Jr, Leon AS. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc.* 2000;32:S498-S516.
18. Miranda H, Viikari-Juntura E, Martikainen R, Takala E-P, Riihimäki H. Physical exercise and musculoskeletal pain among forest industry workers. *Scand J Med Sci Sports.* 2001;11:239-246.

V

IS GENERIC PHYSICAL ACTIVITY OR SPECIFIC EXERCISE ASSOCIATED WITH MOTOR ABILITIES?

by

Rinne M, Pasanen M, Miilunpalo S, Mälkiä E. 2010.

Medicine and Science in Sports and Exercise 42, 1760-1768.

STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH

1 Kirjonen, Juhani, On the description of a human movement and its psychophysical correlates under psychomotor loads. 48 p. 1971.

2 Kirjonen, Juhani ja Rusko, Heikki, Liikkeen kinemaattisista ominaispiirteistä, niiden psykofyysisistä selitysyhteyksistä ja näiden muutoksista psykomotorisen kuormituksen ja kestävyysharjoittelun vaikutuksesta. - On the kinematic charac-teristics and psychophysical correlates of a human movement and their changes during psychomotor loading and endurace conditioning. 156 p. 1971.

3 Sarviharju, Pekka J., Effects of psycho-physical loading and progressive endurance conditioning on selected biochemical correlates of adaptive responses in man. 95 p. 1973.

4 Kiviaho, Pekka, Sport organizations and the structure of society. 54 p. 1973.

5 Komi, Paavo V., Nelson, Richard C. and Pulli, Matti, Biomechanics of skijumping. 53 p. 1974.

6 Meteli, Työolot, terveys ja liikuntakäyttäytyminen metallitehtaissa. Kartoittavan kyselyn aineistot ja toteuttaminen. 178 p. 1974.

7 Tiainen, Jorma M., Increasing physical education students' creative thinking. 53 p. 1976.

8 Rusko, Heikki, Physical performance characteristics in Finnish athletes. 40 p. 1976.

9 Kiiskinen, Anja, Adaptation of connective tissues to physical training in young mice. 43 p. 1976.

10 Vuolle, Pauli, Urheilu elämänsisältönä. Menestyneiden urheilijoiden elämänura kilpailuvuosina - Top sport as content of life. 227 p. 1977.

11 Suominen, Harri, Effects of physical training in middle-aged and elderly people with special regard to skeletal muscle, connective tissue, and functional aging. 40 p. 1978.

12 Viitasalo, Jukka, Neuromuscular performance in voluntary and reflex contraction with special reference to muscle structure and fatigue. 59 p. 1980.

13 Luhtanen, Pekka, On the mechanics of human movement with special reference to walking, running and jumping. 58 p. 1980.

14 Laakso, Lauri, Lapsuuden ja nuoruuden kasvuympäristö aikuisiän liikuntaharrastusten selittäjänä: retrospektiivinen tutkimus. - Socialization environment in childhood and youth as determinant of adult-age sport involvement: a retrospective study. 295 p. 1981.

15 Bosco, Carmelo, Stretch-schortening cycle inskeletal muscle function with special reference to elastic energy and potentiation of myoelectrical activity. 64 p. 1982.

16 Olin, Kalevi, Päätöksentekijöiden viiteryhmät kaupunkien liikuntapolitiikassa. - Reference groups of decision-makers in the sport politics of cities. 155 p. 1982.

17 Kannas, Lasse, Tupakointia koskeva terveyskasvatus peruskoulussa. - Health education on smoking in the Finnish comprehensive school. 251 p. 1983.

18 Contribution of sociology to the study of sport. Festschrift Book in Honour of Professor Kalevi Heinilä. Ed. by Olin, K. 243 p. 1984.

19 Alén, Markku, Effects of self-administered, high-dose testosterone and anabolic steroids on serum hormones, lipids, enzymes and on spermatogenesis in power athletes. 75 p. 1985.

20 Häkkinen, Keijo, Training and detraining adaptations in electromyographic, muscle fibre and force production characteristics of human leg extensor muscles with special reference to prolonged heavy resistance and explosive type strength training. 106 p. 1986.

21 Lahtinen, Ulla, Begåvningshandikappad ungdom i utveckling. En uppföljningstudie av funktionsförmåga och fysisk aktivitet hos begåvningshandikappade ungdomar i olika livsmiljöer. 300 p. 1986.

22 Silvennoinen, Martti, Koululainen liikunnanharrastajana: liikuntaharrastusten ja liikuntamotiivien sekä näiden yhteyksien muuttuminen iän mukana peruskoululaisilla ja lukiolaisilla. - Schoolchildren and physically active interests: The changes in interests in and motives for physical exercise related to age in Finnish comprehensive and upper secondary schools. 226 p. 1987.

23 Pohjolainen, Pertti, Toimintakykyisyys, terveydentila ja elämäntyyli 71-75-vuotiailla miehillä. - Functional capacity, health status and life-style among 71-75 year-old men. 249 p. Summary 13 p. 1987.

24 Mero, Antti, Electromyographic acticity, force and anaerobic energy production in sprint running; with special reference to different constant speeds ranging from submaximal to supramaximal. 112 p. Tiivistelmä 5 p. 1987.

25 Parkatti, Terttu, Self-rated and clinically measured functional capacity among women and men in two age groups in metal industry. 131 p. Tiivistelmä 2 p. 1990.

26 Holopainen, Sinikka, Koululaisten liikuntataidot. - The motor skills of schoolboys and girls. 217 p. Summary 6 p. 1990.

27 Numminen, Pirkko, The role of imagery in physical education. 131 p. Tiivistelmä 10 p. 1991.

28 Talvitie, Ulla, Aktiivisuuden ja omatoimivuuden kehittäminen fysioterapian tavoitteena. Kehittävän työntutkimuksen sovellus lääkintävoimistelijan työhön. - The development of activity and self-motivation as the aim of physiotherapy. The application of developmental work research in physiotherapy. 212 p. Summary 8 p. 1991.

29 Kahila, Sinikka, Opetusmenetelmän merkitys prososiaalisessa oppimisessa - auttamis-

käyttäytymisen edistäminen yhteistyöskentelyn avulla koululiikunnassa. - The role of teaching method in prosocial learning - developing helping behavior by means of the cooperative teaching method in physical education. 132 p. Summary 2 p. 1993.

30 Liimatainen-Lamberg, Anna-Ester, Changes in student smoking habits at the vocational institutions and senior secondary schools and health education. 195 p. Yhteenveto 5 p. 1993.

31 Keskinen, Kari Lasse, Stroking characteristics of front crawl swimming. 77 p. Yhteenveto 2 p. 1993.

32 Rantanen, Taina, Maximal isometric strength in older adults. Cross-national comparisons, background factors and association with Mobility. 87 p. Yhteenveto 4 p. 1994.

33 Lusa, Sirpa, Job demands and assessment of the physical work capacity of fire fighters. 91 p. Yhteenveto 4 p. 1994.

34 Cheng, Sulin, Bone mineral density and quality in older people. A study in relation to exercise and fracture occurrence, and the assessment of mechanical properties. 81 p. Tiivistelmä 1 p. 1994.

35 Koski, Pasi, Liikuntaseura toimintaympäristös-sään. - Sports club in its organizational environment. 220 p. Summary 6 p. 1994.

36 Juppi, Joel, Suomen julkinen liikuntapolitiikka valtionhallinnon näkökulmasta vuosina 1917-1994. - Public sport policy in Finland from the viewpoint of state administration in 1917-1994. 358 p. Summary 7 p. 1995.

37 Kyröläinen, Heikki, Neuromuscular performance among power- and endurance-trained athletes. 82 p. Tiivistelmä 3 p. 1995.

38 Nyandindi, Ursuline S., Evaluation of a school oral health education programme in Tanzania: An ecological perspective. 88 p. Tiivistelmä 2 p. 1995.

39 Heikinaro-Johansson, Pilvikki, Including students with special needs in physical education. 81 p. Yhteenveto 4 p. 1995.

40 Sarlin, Eeva-Liisa, Minäkokemuksen merkitys liikuntamotivaatiotekijänä. - The significance of self perception in the motivational orientation of physical education. 157 p. Summary 4 p. 1995.

41 Lintunen, Taru, Self-perceptions, fitness, and exercise in early adolescence: a four-year follow-up study. 87 p. Yhteenveto 5 p.1995.

42 Sipilä, Sarianna, Physical training and skeletal muscle in elderly women. A study of muscle mass, composition, fiber characteristics and isometric strength. 62 p. Tiivistelmä 3 p. 1996.

43 Ilmanen, Kalervo, Kunnat liikkeellä. Kunnallinen liikuntahallinto suomalaisen yhteiskunnan muutoksessa 1919-1994. - Municipalities in motion. Municipal sport administration in the changing Finnish society 1919-1994. 285 p. Summary 3 p. 1996.

44 Nummela, Ari, A new laboratory test method for estimating anaerobic performance characteristics with special reference to sprint running. 80 p. Yhteenveto 4 p. 1996.

45 Varstala, Väinö, Opettajan toiminta ja oppilaiden liikunta-aktiivisuus koulun liikuntatunnilla. - Teacher behaviour and students' motor engagement time in school physical education classes. 138 p. Summary 4 p. 1996.

46 Poskiparta, Marita, Terveysneuvonta, oppimaan oppimista. Videotallenteet hoitajien terveysneuvonnan ilmentäjinä ja vuorovaikutustaitojen kehittämismenetelmänä. - Health counselling, learning to learn. Videotapes expressing and developing nurses´ communication skills. 159 p. Summary 6 p. 1997.

47 Simonen, Riitta, Determinants of adult psychomotor speed. A study of monozygotic twins. - Psykomotorisen nopeuden determinantit identtisillä kaksosilla. 49 p. Yhteenveto 2 p. 1997.

48 Nevala-Puranen, Nina, Physical work and ergonomics in dairy farming. Effects of occupationally oriented medical rehabilitaton and environmental measures. 80 p. (132 p.) 1997.

49 Heinonen, Ari, Exercise as an Osteogenic Stimulus. 69 p. (160 p.) Tiivistelmä 1 p. 1997.

50 Vuolle, Pauli (Ed.) Sport in social context by Kalevi Heinilä. Commemorative book in Honour of Professor Kalevi Heinilä. 200 p. 1997.

51 Tuomi, Jouni, Suomalainen hoitotiede-keskustelu. - The genesis of nursing and caring science in Finland. 218 p. Summary 7 p. 1997.

52 Tolvanen, Kaija, Terveyttä edistävän organisaation kehittäminen oppivaksi organisaatioksi. Kehitysnäytökset ja kehittämistehtävät terveyskeskuksen muutoksen virittäjänä. - Application of a learning organisation model to improve services in a community health centre. Development examples and development tasks are the key to converting a health care. 197 p. Summary 3 p. 1998.

53 Oksa, Juha, Cooling and neuromuscular performance in man. 61 p. (121 p.) Yhteenveto 2 p. 1998.

54 Gibbons, Laura, Back function testing and paraspinal muscle magnetic resonance image parameters: their associations and determinants. A study on male, monozygotic twins. 67 p (128 p.) Yhteenveto 1p. 1998.

55 Nieminen, Pipsa, Four dances subcultures. A study of non-professional dancers´ socialization, participation motives, attitudes and stereotypes. - Neljä tanssin alakulttuuria. Tutkimus tanssinharrastajien tanssiin sosiaalistumisesta, osallistumismotiiveista, asenteista ja stereotypioista. 165 p. Yhteenveto 4 p. 1998.

56 Laukkanen, Pia, Iäkkäiden henkilöiden selviytyminen päivittäisistä toiminnoista. - Carrying

out the activities of daily living among elderly people. 130 p. (189 p.). Summary 3 p. 1998.

57 AVELA, JANNE, Stretch-reflex adaptation in man. Interaction between load, fatigue and muscle stiffness. 87 p. Yhteenveto 3 p. 1998.

58 SUOMI, KIMMO, Liikunnan yhteissuunnittelumetodi. Metodin toimivuuden arviointi Jyväskylän Huhtasuon lähiössä. - Collaborative planning method of sports culture. Evaluation of the method in the Huhtasuo suburb of the city of Jyväskylä. 190 p. Summary 8 p. 1998.

59 PÖTSÖNEN, RIIKKA, Naiseksi, mieheksi, tietoiseksi. Koululaisten seksuaalinen kokeneisuus, HIV/AIDS-tiedot, -asenteet ja tiedonlähteet. - Growing as a woman, growing as a man, growing as a conscious citizen. 93 p. (171 p.). Summary 3 p. 1998.

60 HÄKKINEN, ARJA, Resistance training in patients with early inflammatory rheumatic diseases. Special reference to neuromuscular function, bone mineral density and disease activity. - Dynaamisen voimaharjoittelun vaikutukset nivelreumaa sairastavien potilaiden lihasvoimaan, luutiheyteen ja taudin aktiivisuuteen. 62 p. (119 p.) Yhteenveto 1 p. 1999.

61 TYNJÄLÄ, JORMA, Sleep habits, perceived sleep quality and tiredness among adolescents. A health behavioural approach. - Nuorten nukkumistottumukset, koettu unen laatu ja väsyneisyys. 104 p. (167 p.) Yhteenveto 3 p. 1999.

62 PÖNKKÖ, ANNELI, Vanhemmat ja lastentarhanopettajat päiväkotilasten minäkäsityksen tukena. - Parents´ and teachers´ role in selfperception of children in kindergartens. 138 p. Summary 4 p. 1999.

63 PAAVOLAINEN, LEENA, Neuromuscular characteristics and muscle power as determinants of running performance in endurance athletes with special reference to explosive-strength training. - Hermolihasjärjestelmän toimintakapasiteetti kestävyyssuorituskykyä rajoittavana tekijänä. 88 p. (138 p.) Yhteenveto 4 p. 1999.

64 VIRTANEN, PAULA, Effects of physical activity and experimental diabetes on carbonic anhydrace III and markers of collagen synthesis in skeletal muscle and serum. 77 p. (123 p.) Yhteenveto 2 p. 1999.

65 KEPLER, KAILI, Nuorten koettu terveys, terveyskäyttäytyminen ja sosiaalistumisympäristö Virossa. - Adolescents' perceived health, health behaviour and socialisation enviroment in Estonia. - Eesti noorte tervis, tervisekäitumine ja sotsiaalne keskkond. 203 p. Summary 4p. Kokkuvõte 4 p. 1999.

66 SUNI, JAANA, Health-related fitness test battery for middle-aged adults with emphasis on musculoskeletal and motor tests. 96 p. (165 p.) Yhteenveto 2 p. 2000.

67 SYRJÄ, PASI, Performance-related emotions in highly skilled soccer players. A longitudinal study based on the IZOF model. 158 p. Summary 3 p. 2000.

68 VÄLIMAA, RAILI, Nuorten koettu terveys kyselyaineistojen ja ryhmähaastattelujen valossa. - Adolescents' perceived health based on surveys and focus group discussions. 208 p. Summary 4 p. 2000.

69 KETTUNEN, JYRKI, Physical loading and later lower-limb function and findings . A study among male former elite athletes. - Fyysisen kuormituksen yhteydet alaraajojen toimintaan ja löydöksiin entisillä huippu-urhelijamiehillä. 68 p. (108 p.) Yhteenveto 2 p. 2000.

70 HORITA, TOMOKI, Stiffness regulation during stretch-shortening cycle exercise. 82 p. (170 p.) 2000.

71 HELIN, SATU, Iäkkäiden henkilöiden toimintakyvyn heikkeneminen ja sen kompensaatioprosessi. - Functional decline and the process of compensation in elderly people. 226 p. Summary 10 p. 2000.

72 KUUKKANEN, TIINA, Therapeutic exercise programs and subjects with low back pain. A controlled study of changes in function, activity and participation. 92 p. (154 p.) Tiivistelmä 2 p. 2000.

73 VIRMAVIRTA, MIKKO, Limiting factors in ski jumping take-off. 64 p. (124 p.) Yhteenveto 2 p. 2000.

74 PELTOKALLIO, LIISA, Nyt olisi pysähtymisen paikka. Fysioterapian opettajien työhön liittyviä kokemuksia terveysalan ammatillisessa koulutuksessa. - Now it's time to stop. Physiotherapy teachers' work experiences in vocational health care education. 162 p. Summary 5 p. 2001.

75 KETTUNEN, TARJA, Neuvontakeskustelu. Tutkimus potilaan osallistumisesta ja sen tukemisesta sairaalan terveysneuvonnassa. - Health counseling conversation. A study of patient participation and its support by nurses during hospital counseling. 123 p. (222 p.) Summary 6 p. 2001.

76 PULLINEN, TEEMU, Sympathoadrenal response to resistance exercise in men, women and pubescent boys. With special reference to interaction with other hormones and neuromuscular performance. 76 p. (141 p.) Yhteenveto 2 p. 2001.

77 BLOMQVIST, MINNA, Game understanding and game performance in badminton. Development and validation of assessment instruments and their application to games teaching and coaching. 83 p. Yhteenveto 5 p. 2001.

78 FINNI, TAIJA, Muscle mechanics during human movement revealed by *in vivo* measurements of tendon force and muscle length. 83 p. (161 p.) Yhteenveto 3 p. 2001.

79 KARIMÄKI, ARI, Sosiaalisten vaikutusten arviointi liikuntarakentamisessa. Esimerkkinä Äänekosken uimahalli. - Social impact

assessment method in sports planning. - The case of Äänekoski leisure pool. 194 p. Summary 3 p. 2001.
80 PELTONEN, JUHA, Effects of oxygen fraction in inspired air on cardiorespiratory responses and exercise performance. 86 p. (126 p.) Yhteenveto 2 p. 2002.
81 HEINILÄ, LIISA, Analysis of interaction processes in physical education. Development of an observation instrument, its application to teacher training and program evaluation. 406 p. Yhteenveto 11 p. 2002.
82 LINNAMO, VESA, Motor unit activation and force production during eccentric, concentric and isometric actions. - Motoristen yksiköiden aktivointi ja lihasten voimantuotto eksentrisessä, konsentrisessa ja isometrisessä lihastyössä. 77 p. (150 p.) Yhteenveto 2 p. 2002.
83 PERTTUNEN, JARMO, Foot loading in normal and pathological walking. 86 p. (213 p.) Yhteenveto 2 p. 2002.
84 LEINONEN, RAIJA, Self-rated health in old age. A follow-up study of changes and determinants. 65 p. (122 p.) Yhteenveto 2 p. 2002.
85 GRETSCHEL, ANU, Kunta nuorten osallisuusympäristönä. Nuorten ryhmän ja kunnan vuorovaikutussuhteen tarkastelu kolmen liikuntarakentamisprojektin laadunarvioinnin keinoin. - The municipality as an involvement environment - an examination of the interactive relationship between youth groups and municipalities through the quality assessment of three sports facilities construction projects. 236 p. Summary 11 p. 2002.
86 PÖYHÖNEN, TAPANI, Neuromuscular function during knee exercises in water. With special reference to hydrodynamics and therapy. 77 p. (124 p.) Yhteenveto 2 p. 2002.
87 HIRVENSALO, MIRJA, Liikuntaharrastus iäkkäänä. Yhteys kuolleisuuteen ja avuntarpeeseen sekä terveydenhuolto liikunnan edistäjänä. - Physical activity in old age - significance for public health and promotion strategies. 106 p. (196 p.) Summary 4 p. 2002.
88 KONTULAINEN, SAIJA, Training, detraining and bone - Effect of exercise on bone mass and structure with special reference to maintenance of exercise induced bone gain. 70 p. (117 p.) Yhteenveto 2 p. 2002.
89 PITKÄNEN, HANNU, Amino acid metabolism in athletes and non-athletes. - With Special reference to amino acid concentrations and protein balance in exercise, training and aging. 78 p. (167 p.) Yhteenveto 3 p. 2002.
90 LIIMATAINEN, LEENA, Kokemuksellisen oppimisen kautta kohti terveyden edistämisen asiantuntijuutta. Hoitotyön ammattikorkeakouluopiskelijoiden terveyden edistämisen oppiminen hoitotyön harjoittelussa. - Towards health promotion expertise through experiential learning. Student nurses' health promotion learning during clinical practice. 93 p. (164 p.) Summary 4 p. 2002.
91 STÅHL, TIMO, Liikunnan toimintapolitiikan arviointia terveyden edistämisen kontekstissa. Sosiaalisen tuen, fyysisen ympäristön ja poliittisen ympäristön yhteys liikunta-aktiivisuuteen. - Evaluation of the Finnish sport policy in the context of health promotion. Relationships between social support, physical environment, policy environment and physical activity 102 p. (152 p.) Summary 3 p. 2003.
92 OGISO, KAZUYUKI, Stretch Reflex Modulation during Exercise and Fatigue. 88 p. (170 p.) Yhteenveto 1 p. 2003.
93 RAUHASALO, ANNELI, Hoitoaika lyhenee – koti kutsuu. Lyhythoitoinen kirurginen toiminta vanhusten itsensä kokemana. - Care-time shortens – home beckons. Short term surgical procedures as experienced by elderly patients. 194 p. Summary 12 p. 2003.
94 PALOMÄKI, SIRKKA-LIISA, Suhde vanhenemiseen. Iäkkäät naiset elämänsä kertojina ja rakentajina. - Relation to aging. Elderly women as narrators and constructors of their lives. 143 p. Summary 6 p. 2004.
95 SALMIKANGAS, ANNA-KATRIINA, Nakertamisesta hanketoimintaan. Tapaustutkimus Nakertaja-Hetteenmäen asuinalueen kehittämistoiminnasta ja liikunnan osuudesta yhteissuunnittelussa. - From togetherness to project activity. A case study on the development of a neighbourhood in Kainuu and the role of physical activity in joint planning. 269 p. Summary 8 p. 2004.
96 YLÖNEN, MAARIT E., Sanaton dialogi. Tanssi ruumiillisena tietona. - Dialogue without words. Dance as bodily knowledge. 45 p. (135 p.) Summary 5 p. 2004.
97 TUMMAVUORI, MARGAREETTA, Long-term effects of physical training on cardiac function and structure in adolescent cross-country skiers. A 6.5-year longitudinal echocardiographic study. 151 p. Summary 1 p. 2004.
98 SIROLA, KIRSI, Porilaisten yhdeksäsluokkalaisten ja kasvattajien käsityksiä nuorten alkoholinkäytöstä ja alkoholinkäytön ehkäisystä. - Views of ninth graders, educators and parents in Pori, Finland on adolescent alcohol use and on preventing alcohol use. 189 p. Summary 3 p. 2004.
99 LAMPINEN, PÄIVI, Fyysinen aktiivisuus, harrastustoiminta ja liikkumiskyky iäkkäiden ihmisten psyykkisen hyvinvoinnin ennustajina. 65–84-vuotiaiden jyväskyläläisten 8-vuotisseuruututkimus. - Activity and mobility as associates and predictors of mental well-being among older adults. 94 p. (165 p.) Summary 2 p. 2004.

hormonaaliset ja molekulaariset vasteet voimaharjoittelussa voimaurheilijoilla. 119 p. (204 p.) Yhteenveto 2 p. 2006.

116 Pajala, Satu, Postural balance and susceptibility to falls in older women. Genetic and environmental influences in single and dual task situations. - Iäkkäiden naisten tasapainokyky yksinkertaisissa sekä huomion jakamista vaativissa tilanteissa ja kaatumisriskiperimän merkitys yksilöiden välisten erojen selittäjinä. 78 p. (120 p.) Yhteenveto 3 p. 2006.

117 Tiainen, Kristina, Genetics of skeletal muscle characteristics and maximal walking speed among older female twins. - Lihasvoiman ja kävelynopeuden periytyvyys iäkkäillä naiskaksosilla. 77 p. (123 p.) Yhteenveto 2 p. 2006.

118 Sjögren, Tuulikki, Effectiveness of a workplace physical exercise intervention on the functioning, work ability, and subjective well-being of office workers – a cluster randomised controlled cross-over trial with one-year follow-up. - Työpaikalla tapahtuvan fyysisen harjoitteluintervention vaikuttavuus toimistotyöntekijöiden toimintakykyyn, työkykyyn ja yleiseen subjektiiviseen elämänlaatuun – ryhmätasolla satunnaistettu vaihtovuorokoe ja vuoden seuranta. 100 p. (139 p.) Tiivistelmä 3 p. 2006.

119 Lyyra, Tiina-Mari, Predictors of mortality in old age. Contribution of self-rated health, physical functions, life satisfaction and social support on survival among older people. - Kuolleisuuden ennustetekijät iäkkäässä väestössä. Itsearvioidun terveyden, fyysisten toimintojen, elämään tyytyväisyyden ja sosiaalisen tuen yhteys iäkkäiden ihmisten eloonjäämiseen. 72 p. (106 p.) Tiivistelmä 2 p. 2006.

120 Soini, Markus, Motivaatioilmaston yhteys yhdeksäsluokkalaisten fyysiseen aktiivisuuteen ja viihtymiseen koulun liikuntatunneilla. - The relationship of motivational climate to physical activity intensity and enjoyment within ninth grade pupils in school physical education lessons. 91 p. 2006.

121 Vuorimaa, Timo, Neuromuscular, hormonal and oxidative stress responses to endurance running exercises in well trained runners. - Neuromuskulaariset, hormonaaliset ja hapettumisstressiin liittyvät vasteet kestävyysjuoksuharjoituksiin hyvin harjoitelleilla juoksijoilla. 93 p. (152 p.) Yhteenveto 3 p. 2007.

122 Mononen, Kaisu, The effects of augmented feedback on motor skill learning in shooting. A feedback training intervention among inexperienced rifle shooters. - Ulkoisen palautteen vaikutus motoriseen oppimiseen ammunnassa: Harjoittelututkimus kokemattomilla kivääriampujilla. 63 p. Yhteenveto 4 p. 2007.

123 Sallinen, Janne, Dietary Intake and Strength Training Adaptation in 50–70 -year old Men and Women. With special reference to muscle mass, strength, serum anabolic hormone concentrations, blood pressure, blood lipids and lipoproteins and glycemic control. - Ravinnon merkitys voimaharjoittelussa 50–70 -vuotiailla miehillä ja naisilla 103 p. (204 p.) Yhteenveto 3 p. 2007.

124 Kasila Kirsti, Schoolchildren's oral health counselling within the organisational context of public oral health care. Applying and developing theoretical and empirical perspectives. 96 p. (139 p.) Tiivistelmä 3 p. 2007.

125 Pyöriä, Outi, Reliable clinical assessment of stroke patients' postural control and development of physiotherapy in stroke rehabilitation. - Aivoverenkiertohäiriöpotilaiden toimintakyvyn luotettava kliininen mittaaminen ja fysioterapian kehittäminen Itä-Savon sairaanhoitopiirin alueella. 94 p. (143 p.) Yhteenveto 6 p. 2007.

126 Valkeinen, Heli, Physical fitness, pain and fatigue in postmenopausal women with fibromyalgia. Effects of strength training. - Fyysinen kunto, kipu- ja väsymysoireet ja säännöllisen voimaharjoittelun vaikutukset menopaussi-iän ohittaneilla fibromyalgiaa sairastavilla naisilla. 101 p. (132 p.) Yhteenveto 2 p. 2007.

127 Hämäläinen, Kirsi, Urheilija ja valmentaja urheilun maailmassa. Eetokset, ihanteet ja kasvatus urheilijoiden tarinoissa. - An athlete and a coach in the world of sports. Ethos, ideals and education in athletes' narratives. 176 p. Tiivistelmä 2 p. 2008.

128 Aittasalo, Minna, Promoting physical activity of working aged adults with selected personal approaches in primary health care. Feasibility, effectiveness and an example of nationwide dissemination. - Työikäisten liikunnan edistäminen avoterveydenhuollossa – työtapojen toteuttamiskelpoisuus ja vaikuttavuus sekä esimerkki yhden työtavan levittämisestä käytäntöön. 105 p. (161 p.) Yhteenveto 3 p. 2008.

129 Portegijs, Erja, Asymmetrical lower-limb muscle strength deficit in older people. - Alaraajojen lihasvoiman puoliero iäkkäillä ihmisillä. 105 p. (155 p.) Yhteenveto 3 p. 2008.

130 Laitinen-Väänänen, Sirpa, The construction of supervision and physiotherapy expertise: A qualitative study of physiotherapy students' learning sessions in clinical education. - Opiskelijan ohjauksen ja fysioterapian asiantuntijuuden rakentuminen: Laadullinen tutkimus fysioterapiaopiskelijan oppimistilanteista työharjoittelussa. 69 p. (118 p.) Yhteenveto 3 p. 2008.

150 PIITULAINEN, HARRI, Functional adaptation of sarcolemma to physical stress. - Lihassolukalvon toiminnallinen mukautuminen fyysiseen kuormitukseen. 103 p. (178 p.) Yhteenveto 2 p. 2010.

151 VILJANEN, ANNE, Genetic and environmental effects on hearing acuity and the association between hearing acuity, mobility and falls in older women. - Kuulon tarkkuuden periytyvyys ja yhteys liikkumiskykyyn sekä kaatumisiin iäkkäillä naisilla. 85 p. (116 p.) Yhteenveto 2 p. 2010.

152 KULMALA, JENNI, Visual acuity in relation to functional performance, falls and mortality in old age. - Heikentyneen näöntarkkuuden vaikutus toimintakykyyn, kaatumisiin ja kuolleisuuteen iäkkäillä henkilöillä. 98 p. (140 p.) Yhteenveto 3 p. 2010.

153 NIVALA, SIRKKA, Kokemuksellinen vanheneminen sotainvalideilla. Suomalaisten sotainvalidien kokemus elämänkulustaan ja ikääntymisestään. - Disabled war veterans and experiential ageing. Finnish disabled war veterans and their experience of the course of their lives and growing older. 178 p. Summary 4 p. 2010.

154 RINNE, MARJO, Effects of physical activity, specific exercise and traumatic brain injury on motor abilities. Theoretical and pragmatic assessment. 86 p. (134 p.) Tiivistelmä 2 p. 2010.