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STANDARD OPERATING PROCEDURES IN SPORTS SCIENCES AND HEALTH PROMOTION PROGRAMS IN DIFFERENT POPULATIONS

IL DOTTORE
LUCA PETRIGNA

IL COORDINATORE
CH.MO PROF. MASSIMILIANO OLIVERI

IL TUTOR
CH.MO PROF. ANTONIO PALMA

IL CO TUTOR
CH.MA PROF.SSA SIMONA PAJAUJIENE

IL CO TUTOR
CH.MO PROF. ANTONINO BIANCO

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Abstract

In recent years, the population is becoming more sedentary and characterized by an increase in the mean age. One of the consequences is a population with a higher risk of chronic diseases, increasing the risk to incur in disability and death. Consequently, health promotion programs, cheaper than interventions, are acquiring an increasingly central role in the politics of Governments. Health promotion programs want to maintain and improve the physical, cognitive, psychical, and social sphere of people. Considering that psychic and social sphere are strictly dependent on the physical condition, the interest of this thesis was on motor tests ideal for health promotion programs.

The motor evaluation can take place through laboratory and field tests. Laboratory tests, usually, are more reliable and valid while field tests can be adopted for a larger population, because they are more economic and quick to propose. Since health promotion is aimed at a general population, field tests were investigated. Furthermore, in other disciplines, replicable and precise protocols are adopted and these are named standard operating procedures (SOPs). Unfortunately, in the field of Sports Sciences, SOPs are still not widely adopted. For this reason, the Ph.D. project wanted to examine SOPs in Sports Sciences and health promotion programs in different populations such as young and older adults, and in a population with special needs. This was carried on through reviews of the literature (review, scoping review, and systematic review and meta-analysis) and original studies that evaluated the Grooved Pegboard Test (GPT).

During *Study 1*, the use of SOPs was considered in a population composed of adolescents for the evaluation of the strength of the lower limbs through vertical jumps. The result of the review highlighted the lack of SOPs in vertical jumps and consequently, SOPs were proposed for the countermovement and the squat jump test.

During *Study 2*, a visually impaired population practicing the sport of goalball was analysed using a scoping review of the literature. Field tests adopted in this sport are different and, consequently, SOPs were proposed for the evaluation of goalball players.

Study 3, through a systematic review of the literature and a meta-analysis on older adults, assessed whether SOPs existed for the assessment of people in dual-task situations. Again, SOPs did not exist and guidelines to execute in the most appropriate way the secondary tasks were proposed.

Study 4 is a pilot study that analysed the influence of a secondary task on the execution of a test to evaluate manual dexterity, the GPT. In conclusion, it was noted that the performance of a cognitive task is more disturbing than a motor task. This study was carried on to provide SOPs for the GPT in a dual-task contest.

Study 5 wanted to evaluate the influence that the time spent on smartphones has on the GPT execution. This study was performed to study if normative data created for the GPT had to be updated. The investigation concluded that in young adults, the time spent on the smartphone does not influence the time to conclude the GPT.

During *Study 6* was investigated if the time to complete the GPT was influenced by the stress level and if a breathing exercise proposed to reduce the stress was useful before the execution of the manual dexterity test. In conclusion, stress does not influence significantly the GPT execution even if it changes the final time. For this reason, it was suggested to adopt, before the execution of the manual dexterity investigation, a short breathing exercise to reduce the effect of the stress.

In conclusion, although the field investigated during these three years is reduced to a few tests and specific populations, it is clear that in the Sports Sciences it is necessary to create and follow SOPs in the evaluation of physical fitness, especially for those populations at risk such as children, adolescents, adults and older adults and people with specific needs, and this thesis provided indications and feedback useful for future studies.

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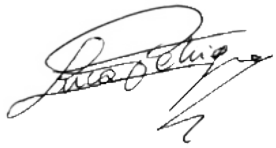

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List of abbreviations

Term	*Description*
GPT	Grooved Pegboard Test
NIH	National Institutes of Health
NIH Toolbox®	NIHTB®
HR	Heart Rate
PICOS	Population, Intervention, Comparison, Outcomes, and Study design
PROSPERO	Prospective Register of Systematic Review
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PRISMA-ScR	PRISMA extension for Scoping Reviews
SOP	Standard Operating Procedure
SOPs	Standard Operating Procedures
VO_{2max}	Maximal Oxygen Consumption
WHO	World Health Organization

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Chapter 1. Overview

1.1 Health promotion

The term health has been defined by the World Health Organization (WHO) as a "complete physical, mental and social well-being, and not merely the absence of disease or infirmity" [1]. This vision of health wants to emphasize the attention on the multiple aspects of this term that is physical, mental, and social. The WHO also highlights that health is a positive status, not an absence of diseases. From the health definition of the WHO, it is clear that the health concept is complex and multifaceted and that it has to combine the physical, emotional, social, spiritual, and intellectual sphere of the human being [2]. Always the WHO in the constitution written in 1946 [1] affirms that any Government should have to promote and protect the health of all people, without distinction of race, economic status, social condition, religion or political belief. Consequently, to be healthy is a right of everyone and everywhere and this has to be guaranteed by the Government.

A properly designed health promotion program, compared with medical intervention or treatment, reduces the health risks and limit the healthcare system costs [3, 4]. Consequently, health promotion should play a fundamental role within the politics and intervention programs of any Governments also considering that the WHO proposed in 2020 new guidelines that can be adopted to reduce sedentary behavior and increase physical activity practice [5].

The concept of health promotion is based on research and it is the science with the aim to allow people the reach of an optimal lifestyle [2]. Furthermore, this science is not interested only in the improvement of the health status, but lifestyle programs should have to increase the capacity to control the overall health characteristics and its determinants [6]. Health promotion programs should involve all populations, from young people to older adults, but also people with special needs. These programs, considering the different people's necessities, should also have to create a proper intervention and not only share health messages and feedback [7]. Furthermore, they should have to act in two directions, one that is general to include different populations, and the second one, the most important, that should include specific components systematically planned and oriented to the singular person [7].

1.2 A Few demographic insights in health promotion campaigns

A rapid rise of overweight and obese children is expected in the next years [8] with a consequence increase of cardiovascular and metabolic risk factors [9]. Children and adolescents should limit the sedentary time, because it is associated with detrimental effects on fitness and cardio-metabolic health, adiposity, and behavioral conduct [5]. Finally, the importance of an intervention in youth is important not only for the immediate effects, but also for the modification of behaviours that will continue into adult life [2]. Considering that not only children, but also young adults are subject to risky behaviours such as physical inactivity, smoking, and drinking, or poor nutrition [10], it is important to plan and adopt appropriate health promotion programs also in adult age.

Related to aging, health promotion programs for older adults are important considering that within 2050 at least one of five people will be over sixty years old [11]. The body composition of older adults is influenced by the natural process due to aging, called sarcopenia [12] with a decrease in muscle mass and strength, of the aerobic and functional capacities, and an increase in the body fat volume [12]. It is documented that strength and power decline from the age of forty with healthy men decreases power and strength more than women [13]. With aging, also several domains of cognitive functions decline such as speed and accuracy of recognition memory performance [14], attentional control and working memory processes [15]. Consequently, health promotion programs for older adults should involve all people and not only those who present specific morbidity [6]. The WHO [11] also suggests an intervention to guarantee a "*healthy aging*", process possible developing and maintaining the functional ability that enables well-being. Similarly, Rowe and Kahn [16] suggested that interventions should guarantee a "*successful aging*" avoiding disability and disease, maintaining high physical and cognitive function, to be engaged in the social sphere and be productive. The intervention to support healthy aging has to present multiple levels, multi-dimensional, and across multiple domains [6, 17]. Usually, a well-planned intervention brings better physical function capacities in older adults [18], decreases all-cause mortality, cardiovascular disease, hypertension, type 2 diabetes, site-specific cancers, mental health problems (reduced symptoms of anxiety and depression), reduces adiposity, improves cognitive health and sleep quality [5]. It also helps in the falls prevention, consequently reducing the falls-related injuries and declines in bone health and functional ability [5]. Furthermore, to guarantee an active and healthy aging, the cognitive health has to be considered by the public health system [19]. This makes important the practice of activities that "exercise the brain" (in general new and challenging) is included [20]. All these benefits are in older adults with and without chronic diseases [21].

It is important to promote the practice of physical activity in people with special needs, indeed, people with disabilities practice less physical activity than people of the same ages [22-24]. This could be caused by physical (i.e. the access to the structures) or social (i.e. the negative attitudes of the society) barriers, or financials limitations [25]. The reduced physical activity practice could cause obesity [26] and it was noted that children with intellectual disability present lower aerobic and muscular fitness than typically developing children [27].

Five measurements should be considered in health promotion programs and these are related to physical and mental health, everyday functioning in social and role activities, and general perceptions of well-being [3]. Accordingly, the American College of Sport Medicine suggests, to improve the mental health status, a program including cardiorespiratory, and resistance training, flexibility and neuro-motor intervention [28]. Therefore, our attention must be focused on these health characteristics.

1.3 Physical activity, physical fitness, and exercise

Caspersen and colleagues in 1985 [29] wrote an article that is a milestone of the literature related to health promotion science, in which the differences between the terms physical activity, physical fitness, and exercise were clarified.

-**Physical activity** is a complex behaviour and it is considered as any movement of the body produced by skeletal muscles that result in energy expenditure and it is positively correlated with physical fitness [29].

-**Physical fitness** is the set of health-related and skill-related components that people have or could achieve [29]. Part of the health-related components are cardiorespiratory endurance, muscular strength, flexibility, and body composition. While agility, postural balance, coordination, power, reaction-time, and speed are skill-related components.

-**Exercise** is considered when physical activity is planned, structured, repetitive, and purposive to improve or maintain one or more components of physical fitness (Caspersen, Powell et al. 1985).

The regular practice of physical activity is suggested due to the numerous physical and mental health benefits reducing the risk of developing cardiovascular heart disease, musculoskeletal disorder, stroke, type 2 diabetes, some forms of cancer, the risk of cognitive decline, and dementia [28, 30, 31]. Ideally, children and youth should participate in at least sixty minutes per day of moderate physical activity and vigorous intensity activities incorporated, mostly aerobic [5, 32]. Muscle strength training has to be also included at least three days per week [5, 32]. The practice of physical activity in children and adolescents improves cardiorespiratory and muscular fitness, blood pressure, dyslipidemia, glucose and insulin resistance, bone health, cognitive outcomes (such as academic performance and executive function) and mental health, and reduces adiposity [5, 33]. Practice of regular physical activity, in childhood, is an aspect of a future healthy life [34]. If the intervention is well structured, it is possible a decrease of weight and body mass index, and an increase in cardiorespiratory fitness, muscle strength, flexibility, postural balance control, blood lipid levels, and glycaemic control [35].

Healthy adults should practice at least 150–300 min/week of moderate-intensity aerobic physical activity or 75–150 min/week of vigorous-intensity aerobic physical activity [5]. Muscle-strengthening activities at moderate or greater intensity that involve all major muscle groups on two or more days a week should be incorporated [5]. In adults, physical activity practice decreases all-cause mortality, cardiovascular disease, hypertension, type 2 diabetes, incident site-specific cancers, mental health (reduced symptoms of anxiety and depression) problems, adiposity levels while improve cognitive health and sleep quality [5].

In older adults, instead, regular physical activity practice reduces the risk of type 2 diabetes, cardiovascular disease, hypertension, osteoporosis, obesity, and sarcopenia [12, 36]. Physical activity decreases the risk of fragility [37] and improves the quality of life reducing the risk of disability [38]. Furthermore, a structured and well planned (in terms of length of the intervention, type, and duration of the sessions) fitness training [39], has benefits on the brain health of older adults making an intervention such as the aerobic exercise a simple and inexpensive way to reduce the effect of the aging process on the brain [40]. Indeed, it was noted that older adults with a high cardiorespiratory fitness were protected against cognitive decline [41]. The effects of aerobic training on cognitive functions improvements are implemented if a mental training program is associated [42]. Furthermore, moderate and high level physical activity practice has positive effects on cognition, such as to the executive and control processes [39], on cognitive processing speed and reducing the cognitive decline [43]. In theory, a physical activity program for successful aging should have varied multicomponent physical activity including cardiorespiratory, flexibility, strength and functional balance training, executed three to five days per week at moderate or greater intensity [5, 44].

The practice of physical activity in people with disability reduces the cardiovascular risks [45], the body fat mass and the body mass index [46, 47], and the medical expenditures [48]. It increases the health-related physical fitness characteristics [29, 47, 49, 50] and functioning [51], postural balance control, muscle strength, quality of life [52]. It also improves the mood, the physical status, the social behaviour and body / shape perception [53], and increase confidence, self-efficacy, and a self-perceived high quality of life [54]. Consequently, it is important to promote physical activity practice for people with disabilities to have benefits of health but also to facilitate inclusion, empowerment, and dignity [55].

In any case and for all populations, according the WHO, it is better to practice some physical activity than none if the minimum suggested cannot be practiced [5].

1.4 Physical fitness characteristics

Caspersen and colleagues in 1985 [29] affirmed in their article that the health-related, more than the skill-related components, are important for public health. The health-related components, as introduced before, are cardiorespiratory endurance, muscular strength, flexibility, and body composition and these are described below.

The cardiorespiratory endurance is the capacity to perform an activity for a long period of time, usually involving different muscles [56]. Cardiorespiratory system is composed of the heart, lungs and blood, and it is related to maximal oxygen consumption also named VO_{2max} [57]. It was noted that the decline of VO_{2max} due to the aging process is related to the loss of metabolically active tissue [58], and consequently, part of the cardiorespiratory system could be also considered the muscle mass. Maximal oxygen consumption is a good estimate for cardiorespiratory fitness and it is an independent marker of early diseases such as coronary artery disease and the progression of atherosclerosis [59]. Cardiorespiratory fitness is positively related to insulin sensitivity, blood lipid profile, body composition, inflammation, and blood pressure [60]. Furthermore, better cardiorespiratory fitness is associated with a lower risk of all-cause mortality and coronary heart events or cardiovascular disease [61].

Muscle strength is divided into dynamic, when a movement is performed, and static, when the force is applied against a fixed object [56]. It exists a strong and inverse association of muscular strength with all-cause mortality and it is confirmed in several clinical populations such as in people with cardiovascular disease, peripheral artery disease, cancer, renal failure, chronic obstructive pulmonary disease, rheumatoid arthritis and patients with critical illness [62]. Moreover, muscle strength is inversely and independently associated with all causes of mortality and cancer [63, 64]. Muscular strength is an important factor since youth, indeed, low muscular strength in adolescence is a risk factor for major causes of death in young adulthood, such as cardiovascular diseases [65]. In older adults, due to the aging process, it presents a decline of lower and upper extremity muscle mass, explosive force, and maximal strength [66, 67]. It is also related to the risk of falls [68]. Fortunately, resistant exercise and especially high-intensity training improves strength [69] but also muscle mass and bone density and it decreases physical limitations [70].

Flexibility is a functional capacity, and it is considered as the capacity of the joints to work properly and consequently to have the ability to move through the full range of the movement [71]. It was noted, how a limited range of motion of the dorsi-flexors in older adults reduces the ability to control standing postural balance but also walking performance [72]. Also, in older adults is possible, with well-planned stretching training programs, to improve flexibility [73, 74] resulting in improvements in gait speed and control [75] and postural balance control [76].

Body composition evaluation is important in order to monitor nutritional level, it is an evaluation suitable for different age groups, and during growth predict increased adult adiposity [77]. The monitor of the weight in growth can be helpful to prevent obesity risk later in life [78].

1.5 Physical fitness evaluation

It is important to educate people to the knowledge and to adopt healthy habits, but also to perform screening to evaluate physical fitness level of the population [30]. The evaluation of physical fitness is important because it is a marker of health status [79] and it is inversely correlated with the risk of all-cause mortality [80, 81]. Furthermore, physical fitness is correlated with a reduction of cardiovascular disease risk factors and an increment of skeletal health [82], and it presents a positive association with cognition and academic achievement [83].

Physical fitness has been considered as a one-dimensional construct composed of different fitness elements included in many fitness tests [84]. In the specific, health-related fitness interventions are composed of tests that can help to create programs to guarantee the general health of the individual, and consequently, body composition, muscular strength, flexibility and cardiorespiratory endurance are more useful than agility, coordination, or other skill-related components [56].

The evaluation of physical fitness can be performed, objectively, and accurately, through laboratory and field tests [85-93]. Three important aspects have to be considered related to the tests and these are reliability, which is the obtaining the same results if the test is repeated, the validity, which is the correspondence between the test and the purpose for which it was created, and the feasibility, which is the real possibility to evaluate what the investigator want to measure [56, 94-96]. While laboratory tests usually present higher reliability, tests performed directly in the field are generally easier to administer and less cost intense [97].

Sport and Exercise Sciences laboratory, University of Palermo

Field evaluation, in comparison to laboratory tests, is more ecologically valid and, consequently, this kind of evaluation results to be suitable in population-based studies such as in a school- or college-setting [92]. In the school-setting, as in the home-based environment, the test would require a few and inexpensive pieces of equipment, the investigator should perform the test easily, and could involve more people at the same time, maybe working with a circuit testing session [56]. It is to highlight that in the last years, an increasing number of test batteries (especially for children and adolescents) to evaluate physical fitness and muscle functionality were created such as the functional muscle screening [98], the AVENA study [99], the FITNESSGRAM [100], and the HELENA study [101].

Cardiorespiratory endurance usually is evaluated with tests that force the organism to reach the VO_{2max} [56]. Laboratory tests for cardiorespiratory fitness are usually performed on a treadmill until the maximal capacity of the participant to process atmospheric oxygen is reached [56] and some examples are the protocols proposed by Bruce [102] and Astrand [85]. The measurement in the laboratory of the VO_{2max} requires costly equipment [56], consequently, these tests are proposed only for high level athletes or to a specific population where accurate VO_{2max} is required. On the other side, there are field tests that are commonly and widely adopted such as the Cooper test [88] and the 20-m Shuttle Run Test [89] that are valid and present a standardized procedure for the estimation of VO_{2max} [103]. Endurance is measured in older adults with a walking test and the evaluation, where is required a lower level intensity, ranges from two minutes to twelve minutes [104] even if the distance that an older adult can walk in six minutes (the so-called six minutes walking test) [105], is the most adopted, and is valid and reliable [106]. Walking tests use also distance parameters and not only the time, and the capacity to walk ten meters [107] is an example.

Muscle strength is usually evaluated through a maximum one-effort exercise, against a resistance, of a muscle or a group of muscles [56]. Tests for dynamic strength evaluation with good validity are the bench press, the pull-up, the dip strength, the standing vertical arm press and spring-scale test [56] but also medicine ball throw, bent arm hang, push-ups, standing broad jump, and trunk lift evaluation [108]. Isometric or isokinetic muscular strength can be evaluated through dynamometry such as the handgrip or dynamometer for back and legs [56], the leg extensors on a leg press, back, knee extension and flexion but also through the Wingate test [108]. Also in older adults, isometric strength can be assessed with dynamometers such as measurements of biceps or quadriceps strength [109]. Lower limb strength in older adults can be assessed also through the five times chair rise test [110]. The handgrip test, the standing broad jump test [92, 111], the curl-up test [112], and the vertical jumps test [113] are field tests widely adopted. While the curl-up and the jumps are ideal field test for young people, the handgrip test can be adopted for different ages. The handgrip strength, especially from the age of 45 years old, is highly predictive of functional limitation, disability, and all-causes of mortality such as inflammation, poor nutritional status, and depression, in healthy people and people with disability [107, 114-116]. Furthermore, grip strength is a long-term predictor of mortality from all-causes, chronic diseases, cardiovascular diseases, and cancer [117, 118].

Flexibility could be evaluated through laboratory tests such as goniometric techniques or photographic methods [56], but also through field tests such as the sit and reach test [119], the stand and reach test, the V sit and reach, and the shoulder stretch [108]. The modified sit and reach test version can be used for older adults to evaluate spinal flexibility [120]. The field tests, even if detect joint laxity, generally present less sensitivity to sample than laboratory tests [56]. The sit and reach test is adopted to evaluate hamstring extensibility, and it presents clear guidelines [119] to ensure reliability [56] and validity [90].

The evaluation of body composition can be done through direct, such as the biopsy, and indirect assessment [56]. There exists a wide range, with different precision and accuracy techniques, to evaluate body composition indirectly such as anthropometry [121], skinfold thickness [122] or densitometry, air displacement plethysmography, tracer dilution, dual-energy X-ray absorptiometry, and bioelectrical impedance analysis [123]. Usually, anthropometric evaluations are less valid than other tests but more feasible for mass testing [56]. An example of a rapid and accurate measurement is the imaging technique that allows visualization and quantification of tissues, organs, or constituents (e.g. muscles and adipose tissue) such as the nuclear magnetic resonance imaging [124] or the computed tomography [123]. Unfortunately, these are expensive and complex evaluation methods [123]. Electrical impedance is reliable, valid, fast, safe and portable, making this test useful for epidemiological studies [56]. Skinfold evaluation is a field test that is simple to be administered [122], cheap, valid and accurate [56]. Another simple and cheap field evaluation method is the hip / waist ratio, a value calculated by dividing the hip (cm) by the waist measurement (cm) [125]. Finally, one of the most adopted test is the body mass index evaluation that it is obtained by the weight (kg) divided by the height squared (m^2) and, as guidelines, body mass index below 18.5 is an index of underweight; between 18.5 and 24.9 is a normal range while between 25 and 29.9 indicates overweight; above 30 indicate that the person is obese [126].

Considering that field tests still require attention, indeed, not always the testing protocols correspond between batteries and studies, the present thesis will focus the attention on field tests evaluation methods.

1.6 Cognitive evaluation

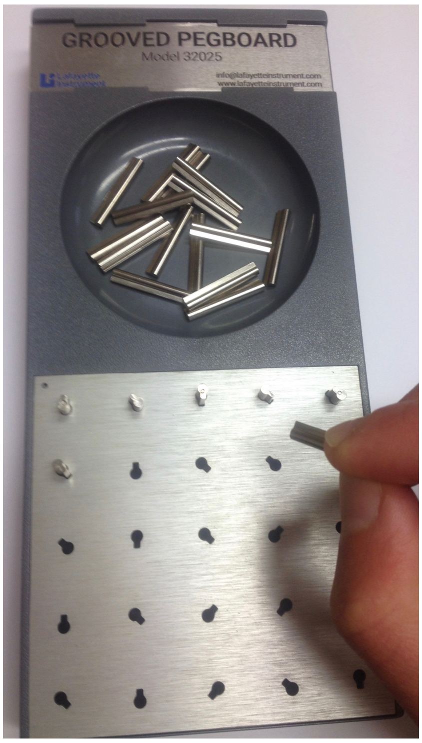
The United States National Institutes of Health (NIH) Blueprint for Neuroscience Research initiative, composed by Sixteen Institutes, centers and offices of the NIH, cooperated in the creation of the the NIH Toolbox® for Assessment of Neurological and Behavioral Function (NIHTB®) (www.nihtoolbox.org). The NIHTB® is a valid, reliable, multidimensional, and versatile tool to evaluate the cognitive, emotional, motor, and sensory function domains to measure neurological and behavioral functions for different disciplines and for different populations (such as a general population, individuals with chronic conditions, and across the lifespan) [127]. The main strength of the NIHTB® is the use of a standard methodology, consequently, the results are not influenced by the instrument. Other strength points are the brevity of application of the tests, the wide age spectrum that range from 3 to 85 years, the adaptability and with the possibility to be updated without losing the continuity or comparability of previously collected data [127], but also the sensitivity, and the low costs. Furthermore, NIHTB® normative scores are available for each year of age.

The NIHTB® contains a total of 108 different tests divided in four modules and different subcategories:

-the *emotion battery* is a component of physical health and on perceptions of life quality [128]. This module is suggested from the age of eight and it wants to evaluate the feelings of the person. It includes several subcategories and these are: i) the psychological well-being (positive affect, general life satisfaction, meaning and purpose evaluation); ii) the stress and self-efficacy (perceived stress and self-efficacy evaluation); iii) the social relationships (social support, companionship, and social distress evaluation); and iv) the negative affect (anger, fear, and sadness evaluation).

-the *sensation battery* includes both, the biochemical and neurologic process of the nerve impulses and the nervous system activity: i) audition (words-in-noise test); ii) vision (visual acuity test); iii) olfaction (odor identification test); iv) pain (pain interference survey and pain intensity survey test); v) taste (regional taste intensity test); vi) quality of life (vision-related quality of life evaluation); vii) hearing-related disability (hearing handicap inventory) are the subcategories of this module. Regarding to pain module, it is not recommended for children [129].

-the *motor battery* is composed by tests that evaluate the ability to use and control muscles and movements and it is recommended from the age of seven. Motor assessment subcategories included in this module evaluate i) manual dexterity (9-hole pegboard dexterity test); ii) strength (handgrip strength test); iii) postural balance control (standing balance test); iv) locomotion (4-m walk gait speed test); and v) endurance (2-min walk endurance test) [130].



GPT execution

-the *cognition battery* wants to evaluate mental processes that interest knowledge and comprehension and it is recommended from the age of seven. Different subdomains were included in this module and these are i) attention and executive functioning (Flanker inhibitory control and attention test, dimensional change card sort test); ii) episodic memory (picture sequence memory test); iii) language (picture vocabulary test and oral reading recognition test); iv) processing speed (pattern comparison processing speed test, oral symbol digit test, and auditory verbal learning); and v) working memory (list sorting working memory test) [131].

It is important to note that the time spent to complete the GPT is influenced by several factors such as the participants' age [132], gender [132-134], and education [132, 135]. Factors such as new technologies as the smartphones or the role of stress has not been yet investigated making necessary further investigations to evaluate what could influence the GPT.

Related to cognitive functions, since 2000, these are deeply studied in the so called dual-task condition [136]. The dual-task paradigm consists in simultaneous performance of a primary static (usually postural control on a firm surface) or dynamic (postural control on a no-fixed surface or a walking test) with a secondary task [137] that could be motor or cognitive [138]. The secondary task modifies the primary task, such as a postural stability task that is influenced by the execution of the secondary task [139, 140].

Different models were proposed to explain the dual-task paradigm [141] and these are:

-the *capacity sharing model* in which the mental resources are shared among primary and the secondary tasks.

-the *bottleneck model*. According to this theory, when similar tasks (primary and secondary) are proposed, these adopt a similar process.

-the *cross-talk model* in which two similar tasks (primary and secondary) activate the same process and they present an improvement in the final performance.

In the literature [138, 142] exists a wide range of secondary tasks and these could be divided in working memory, mental training, reaction time, manual, discrimination and decision making, and verbal fluency tasks. Even if a study [143] was conducted to understand the effects of the performance of different secondary tasks during training programs, further investigations are still required.

In older adults, it was noted that when the complexity of a task, either primary or secondary, is increased, usually they present a decrease in the primary task performance [140, 144, 145]. The decrease of the postural control capacity in a dual-task setting [146] could be explained by the deterioration of the postural control system that is composed by the vision, the proprioception, and the vestibular system [147, 148]. The increase of postural sway could be explained also by the inability, that older adults especially have, to allocate attention in the postural control task [136, 140, 145]. Unfortunately, the reduction of postural control capacity in older adults increases the risk of falls [136, 144] making this topic interesting for the community.

1.7 Standard Operating Procedures

In Sports Sciences field, during assessment is strongly suggested to adopt a standardized procedure especially in physical fitness context more than in elite athletes, where the personalisation of the protocol to evaluate specific-tasks could be required. The use of a protocol in high-level athletes created for sedentary people does not help coaches and athletes to know the physical and mental limits.

In other fields is widely adopted the standard operating procedure also named SOP or in its plural form SOPs and these are documents that provide details of a process to allow the correct repetition of the protocol [149, 150]. Standard operating procedures are widely adopted in a lot of disciplines in which guidelines are required to limit the risk factors [149], such as aviation, nuclear power plants, offshore oil industry, hospital emergency care, and emergency response services [151]. These SOPs are also adopted in other fields such as in the prevention of musculoskeletal disorders and an example is in the ergonomic environment [152], but also in the management for diagnosis and treatment in pathologies such as rheumatic diseases in children and young adults [153].

Standard Operating Procedures in Sports Sciences contest are adopted in few studies and most of them are to a medical environment, such as patients with inflammatory arthritis [154] or people with a chronic respiratory disease [155, 156] and they created SOPs for the six minutes' walk test, the incremental shuttle walks test, and the endurance walk test. To the best of our knowledge, only a study adopted SOPs in the physical fitness contest explicitly and it is a study where different countries were involved [157, 158]. Due to the necessity to follow the same guidelines in different countries and ensure data collection quality and consistency, the investigators of the study had to create and follow SOPs [157, 158].

The creation and adoption of SOPs in the research field have several advantages:

-the first point to highlight is that a SOP makes the study procedure safer, preventing investigators, coaches or trainer misconducts or mistreatments, or potential legal or ethical issues, especially when the population is composed by children [159].

-the second point is that the knowledge of the "what" and the "how" to do before, during and after the investigation is fundamental for the success and the safety of the activities [151].

-a third point to highlight is the necessity of SOPs if the comparison of the scientific literature and the creation of normative data is required.

For the reasons highlighted above, it is important in the future to systematically use SOPs also in the physical fitness field, especially in a health promotion context. Only in this way it will be possible to generalize easily the findings and contextualize the results with the existing literature. On the other side, considering that the NIHTB® is standardized, the research on this topic should have to evaluate if new confounding factors (such as smartphones), recent research fields such as dual-task activities or the stress (mental or physical) influence the performance of these evaluations and, consequently, if new SOPs are required.

Chapter 2. Rationale and study description

2.1 Rationale for the studies included

A method widely adopted to analyse the literature is through reviews of literature that since the 1970s, when the first systematic review in healthcare was published [160], have increased. There are different types of reviews and the following is a list of typologies of reviews proposed by Grant and Booth [161]:

-The *review of literature*. It provides information on a topic and eventually the necessity of further research.

-The *systematic review*. It systematically collects and synthesizes the literature related to a topic ideally following guidelines and reporting the methods to allow other investigators to replicate the process.

-The *meta-analysis* adopted to obtain precise effect of the results of quantitative studies through the statistic. Usually, to perform the meta-analysis is required a systematic review. Furthermore, the studies that can be included in the meta-analysis have to be similar in the population, intervention and comparison characteristics and especially they must have the same measures or outcomes.

-The *systematized review*. It adopts some elements of the process of a systematic review. They cannot draw upon the resources required for a full systematic review.

-The *critical review*. It is adopted when the literature was extensively researched and aims to demonstrate that the writer has extensively researched and critically evaluated the literature. The main characteristics of this kind of review are articles that are analysed and synthesized from diverse sources.

-The *literature review*, also named *narrative review*. It is a collection of recent or current published articles. It requires a process for the articles identification and inclusion, synthesis with text, tables or graphs, and perform a sort of analysis. It is used to identify the gaps and to prepare the basis for future review or research.

-The *scoping review*. It provides a preliminary assessment of the potential size and scope of the literature on a topic with the aim to identify the nature and extent of research evidence.

-The *mapping review* is similar to a scoping review but it also includes further review and original studies and the outcome is not known beforehand.

-The *mixed methods review*. It is a combination of methods that include at least one literature review.

-An *overview* consists of any kind of summary to survey and describe the medical literature.

-The *qualitative systematic review* wants to evaluate, integrate and compare the findings of qualitative studies. The goal of this kind of study is the interpretation and understanding of a phenomenon to develop a new theory.

-The *rapid review*. It wants to assess, through the systematic review methods, what is about a policy or practice issue.

-The *state-of-the-art reviews* are a subtype of literature review to address more current matters.

-The *umbrella review*. It aggregates findings from several reviews that address specific questions and focuses on a broad condition or problem for which there are two or more potential interventions and highlights reviews that address these potential interventions and their results.

Considering the description made in the list [161], systematic review with a meta-analysis is the method that better synthesize the literature, also in a quantitative way, indeed, it is replicable and limits the risk of bias and imprecision [162]. To perform a high-quality systematic review and meta-analysis, the PRISMA statement [163] was suggested to be adopted. The PRISMA statement [163] is composed by 27 items and they are divided to provide information for the title, abstract, introduction, methods, results, discussion, and funding. In general, for the title it is important to specify if the study is a systematic review, meta-analysis or both. The abstract has to be structured and it should include the background, objectives, methods, results, limitations and conclusions. Part of the introduction are the rationale and the objectives. The methods have to include the protocol or the registration number, eligibility criteria for the populations, interventions, comparisons, outcomes and study design (PICOS), the method of the search strategy, the study selection and the data collection, but also the bias assessment, and how the results will be synthesized. The results should contain all the parts presented in the methods, the discussion, instead, should be composed by the summary of evidence, limitations and conclusions. Finally, the funding information have to be provided. The following of the procedure will make the review systematic and consequently replicable thereby improving the quality of the research.

The "scoping review" is also a good method to synthetize the literature around a topic, by systematically searching, selecting, and synthesizing the knowledge, wants to clarify working definitions, detect knowledge gaps, scope a body of literature, clarify concepts, investigate research conduct, mapping main concepts or theories of a topic or field, types of evidence, or sources in the research [164-167]. Moreover, it is useful when the literature has not yet been comprehensively reviewed [164-167]. The number of scoping reviews published per year has increased since 2012 [168] even if a lot of them present poor methodological and reporting quality [166]. For this reason, it was suggested to use PRISMA-ScR checklist and explanation. The checklist contains 20 essential reporting items and 2 optional items [166]. The sections of PRISMA-ScR guidelines are similar to PRISMA statement [163] apart that the bias assessment is not required.

Systematic and scoping reviews are good example of structured review, but to provide information on a topic, non-structured review are also a useful method [161]. For this reason, according to the topic studied, it was decided to evaluate the literature adopting a review of the literature (*study 1*), a scoping review (*study 2*), and a systematic review and meta-analysis (*study 3*).

The first purpose of this thesis was to investigate throw the analysis of the scientific literature to study if SOPs in Sports Sciences were adopted in the evaluation of different population (adolescents, people with disabilities, and older adults), and eventually to propose SOPs to fill the gap. The topics analysed were vertical jumps for the assessment of muscle strength in adolescents (*study 1*), goalball for a visually impaired population (*study 2*), and dual-task activities in older adults (*study 3*).

As systematic reviews, also experimental studies need to follow a procedure and, as it is suggested [169], there are some aspects to consider. The study should present a structured introduction that analyse the literature and conduct the reader to the hypothesis. It is important to adopt a structured method section which has to include information related to:

-*participants* characteristics (i.e. sample size, age, gender, weight, height, level of training…)

-description of the *instruments* (i.e. validity, reliability, feasibility…)

-*procedure* adopted (i.e. data collection process and treatment of the participants…)

-*statistical analysis* which is the method that allow the interpretation, description and evaluation of the relationships of the data collected.

The methods are followed by the results that should include all the findings also adopting tables, graphs, and figures to graphically help the reader to better understand them. The results should be discussed objectively adopting the existing scientific literature on the topic, highlighting the limits and providing indications for future studies. Usually, the study end with the conclusions that summarize the main findings.

The purpose of the original studies performed was to investigate the GPT confounding factors such the performance of a secondary motor and cognitive task while the test was performed (*study 4*), the time spent on the smartphone (*study 5*), or the role of the stress (physical and mental) (*study 6*), and consequently to propose SOPs also for this manual dexterity test.

In the following paragraphs the studies performed are synthetized.

2.2 Study 1

A Review of Countermovement and Squat Jump Testing Methods in the Context of Public Health Examination in Adolescence: Reliability and Feasibility of Current Testing Procedures

In *study 1*, the vertical jumps technique in adolescents adopted in the literature were evaluated. This testing method is widely used to measure lower limb extremities muscular fitness because it is a simple but informative test [170, 171] and a fundamental movement skill [172]. The countermovement and squat jump are two examples of vertical jumps which are both derived from the Sargent jump [173, 174] and these two jumps techniques were analysed. The countermovement jump provides information about the lower limbs reactive strength performance [175] while the squat provides information about the legs' concentric power performance [175, 176]. Both vertical jumps are considered reliable and valid [177] also in populations such as young children [178], sedentary, and elite athletes [173, 174, 179-181] making this test an easy and cheap tool to evaluate explosive muscle strength. A lack of robust and consistent testing methods for the vertical jumps evaluation techniques compromises the quality of research in this area [182, 183]. Consequently, it was decided to carry out a review of the literature.

From a methodological point of view, PRISMA statement [163] was partially adopted. The following key points were not used: protocol and registration, data items, risk of bias in individual studies, summary measures, synthesis of results, risk of bias across studies, additional analyses, risk of bias within studies, results of individual studies, and synthesis of results. The information related to the jumps phases was collected in a Microsoft Excel® (Microsoft Corp, Redmond, Washington) spreadsheet and discussed in a narrative way. Participants were healthy adolescents aged between 12 and 18 years while elite athletes were excluded. Eligibility criteria were not for intervention, comparisons, and outcomes of the studies. Only English written original articles were included.

The studies were collected from PubMed, Web of Science and Scopus using different terms (i.e. countermovement jump*, squat jump*, vertical jump*, maximal dynamic strength, field test*, physical fitness, reliability…) matched with the Boolean operator (AND). Studies published between January 1st 2009 and July

8th 2019 were collected in EndNote (EndNote version X8; Thompson Reuters, New York, NY) to find duplicates. After the studies collection, two investigators worked independently to select the eligible studies in a screening performed by title, abstract, and full-text. A third investigator was involved if there was disagreement. The screening process was presented in a PRISMA flow diagram.

From the studies, the following information were recorded: first author, year of publication, sample size, participants' age (range, mean, and standard deviation), gender, aim, physical activity level, jump method used, devise adopted, and main results. A descriptive analysis of the countermovement and the squat jump test was adopted to present the results.

A total of 119 studies was included and these were divided into subgroups (studies that adopted only the countermovement jump test; studies that adopted only the squat jump test; studies that adopted both the vertical jumps test). Both the vertical jumps adopted different protocols, the procedure developed by Bosco and colleagues in 1983 [184] was the most adopted, five times for the countermovement jump test [113, 185-188] and three times for the squat jump test [113, 185, 188]. Also, three works [189-191] used the protocol of Bosco but citing his work of 1994 [192] for the squat jump test.

Because there was not a protocol adopted by the majority of the studies, it was decided to analyse the vertical jumps dividing them in phases following the definition proposed by Bobbert and colleagues [193]: starting position (i.e. position of the legs, position of the feet, knee angle), start of push-off (i.e. downward movement depth and velocity), toe-off (i.e. indication given to the participants), and apex of the jump (i.e. maintain legs extended or not). Additionally, the landing phase (i.e. knee fully extended, with both feet, with toes on the same spot) was added. Furthermore, attention was paid on the arm position (i.e. on hips, waist, akimbo position or swim allowed); if participants could use the shoes or not; the number of jumps performance trials (two, three or more than three); and the devices (i.e. force plates, jump mats, photoelectric cell system, Vertex, and video analysis) used for the vertical jumps assessment.

After a careful analysis, a summary was provided in table 1.

Table 1. *Standard operating procedures proposed for the countermovement jump and the squat jump*

Table 1. Standard Operating Procedures proposed for the countermovement jump and the squat jump			
Phase	***countermovement jump***	***squat jump***	
Starting position	Erect position - trunk straight - knee angle of 180° - feet shoulder width apart. Maintain the position for at least 2 seconds	Squat position with trunk straight - knee angle flex at 90° - feet shoulder width apart. Maintain the position for at least 2 seconds	
Push-off	Downward movement: knees angle are flexed (about) 90°	No coutermovemen	
Toe-off	Maximal effort and explosive VJ	Maximal effort and explosive VJ	
Apex	Maintain legs extended	Maintain legs extended	
Landing	Feet together- knees extended at an angle of about 180°	Feet together- knees extended at an angle of about 180°	
Warm-up suggested	Two sets of the following exercises: standing on one leg and nod head gently for 30 seconds; single leg airplane squat with hip thrust (20 repetitions); single leg airplane squat with trunk rotation (20 repetitions); single leg airplane squat with a black theraband resistance applied to the knee that includes trunk rotation with a dumbbell held in the hand (10 repetitions); monster walk with a black theraband resistance positioned around the forefoot, forwards and backwards (3 m each way); monster walk with a black theraband positioned around the forefoot, side-to-side i.e. left and right (3 m each way) (Pinfold et al., 2018)		
Hands	On hips		
Barefoot	No		
Jumps	Best of 5		
Rest	1 minute between		
Device	Photoelectric system		
Best jump	Countermovement jump		

The main finding of *study 1* suggests that both vertical jumps present different testing methods where the protocol for the countermovement jump test proposed by Bosco and colleagues [184] was used in only 5 out of the reviewed 100 original works. The squat jump test developed from protocols of Bosco and colleagues [184, 192] was fully replicated in 3 out of the considered 64 articles included. Consequently, it was necessary to create SOPs for both vertical jumps tests and these could be adopted in the health promotion and health investigation context. The SOPs suggested in the manuscript was reached after the literature analysis, the torso upright position during the starting position phase for both jumps testing methods was suggested to emphasize the use of leg extensors muscles [195, 196]. The position of the knee angle during the push-off phase influences the performance by either increasing or decreasing jump height and consequently the power measured [197, 198] requiring it to be standardized. The fixed position of the arms was proposed to avoid the contribution of upper limbs as well as to eliminate a confounding variable which impacts jump performances [199-202]. Furthermore, the instruction to maintain both legs fully extended starting from the toe-off to the landing phase (i.e. for the entire duration of the apex of the jump phase) is of crucial importance as this can affect the accuracy of the flight time [203]. As with the previous phases, the landing phase was standardized to obtain similar results during the execution of the jumps [203]. According to Bui and colleagues [204] there are different factors such as the landing with the feet nearly flat or with the legs bent that can alter the flight time, distorting the calculated height. Therefore, it is important to land with straight legs, on the forefoot [204] and at the same time amortizing the movement because a stiffer technique increases the risk of injuries [205].

2.3 Study 2

Physical fitness assessment in Goalball: A scoping review of the literature

The interest in the adoption of SOPs was focused also on special needs population such as visually impaired people. A scoping review was performed on goalball, a Paralympic sport, widely practiced by elite athletes, but also in the schools and in the recreational setting [46, 47, 49, 206-211]. In particular, the attention was on the tests adopted to evaluate physical fitness characteristics in these athletes.

The practice of goalball reduces the percentage of body fat and body mass index [46, 47], as well having positive effect on health-related physical fitness characteristics such as cardiorespiratory endurance, muscular strength, muscular endurance, and flexibility [29, 47, 49]. Positive effects are also on postural balance control capacity [47, 49], auditory reaction speed and duration of hearing [212]. The Brockport Physical Fitness test manual [213] is a test battery adopted in the evaluation of goalball athletes and it consists of four to six test items to evaluate aerobic capacity (1 mile run / walk test), body composition (skinfold thickness of triceps and calf) and musculoskeletal functioning (curl-up, trunk lift, push-up and shoulder-stretch tests). The objectives of the review were to study the tests adopted to evaluate visually impaired goalball athletes, to find the common aspects between the testing procedure adopted and, eventually, to propose SOPs.

The review of literature adopted the PRISMA-ScR checklist and explanation [166]. English original studies were included if participants were visual impaired goalball athletes with a classification of B1, B2, or B3. All kinds of interventions and comparisons were included if goalball was evaluated.

Studies were sourced from the electronic databases PubMed, Web of Science and Scopus and included if published between January, 1st 2000 and March, 4th 2020. The term goalball was matched with “physical fitness”, “sports physiology”, “performance analysis” with the Boolean indicator “AND” or “OR”. Data selection followed a two-step process during which duplicates were deleted through the program EndNote X8 (EndNote version X8; Thompson Reuters, New York, USA), while two examiners selected them against the eligibility criteria in a selection by title, abstract and full-text. In case of disagreement between the two examiners, a third examiner considered the study. In a Microsoft Excel spreadsheet (Microsoft Corp; Redmond, Washington, USA) first author and year of publication, sample size and gender, participants' age (range, mean and standard deviation), and tests adopted were collected. The health-related components were categorized into muscular strength, aerobic capacity, postural control, range of motion, flexibility, percentage body fat, and battery adopted. Information was extracted from any part of the study and the results were analysed through a narrative synthesis. Seven studies were included and results are summarized in table 2.

Table 2. *Information regarding the test adopted*

Health-related component	*Test adopted*	*N of time*
Muscular strength evaluation	Isokinetic measurement	2
	Handgrip evaluation	2
	Vertical jump	3
	Curl-ups	2
	Push-ups	2
Cardiorespiratory evaluation	Incremental test on a treadmill	1
	One mile run / walk test	2
	Yo-yo IR1	1
Postural balance evaluation	Laboratory evaluation	2
	Field evaluation Flamingo Balance Test	1
Range of motion	Standard goniometric measures	1
Flexibility evaluation	Sit and reach test	1
	Back-saver sit and reach test	1
	Shoulder-stretch test	2
	Trunk lift test	2
Percentage body fat evaluation	2 site skinfold thickness	2
	7 sites skinfold thickness	1
Test battery	Brockport Physical Fitness Test	2

Study 2 concluded that there is a lack of standardization with a wide variety of tests proposed for goalball athletes. It was noted that there are common aspects evaluated such as physical fitness characteristics (body fat percentage, muscular strength and endurance, aerobic capacities and flexibility) but also anaerobic capacity and postural balance control capacity. Consequently, the study suggested the adoption of the Brockport Physical Fitness Test containing the following tests as SOP: the sit and reach test and shoulder-stretch for flexibility; 1 mile run / walk test for aerobic capacity; curl-up and push-up for muscular strength and endurance; and the two-point skinfold thickness to evaluate the body fat. Furthermore, the Flamingo balance test for postural control capacity, especially in the health-related contest, should be included. The measurement of the thickness of the skinfolds with two-points [47, 207] was suggested because it is a fast and good solution to obtain information regarding the body fat status for athletes but especially in the health promotion setting. The sit and reach test [49] is a valid test for the assessment of hamstring extensibility [90]. For aerobic and anaerobic capacities, considering the difficulties in the locomotor tasks where changes of direction are required, the 1 mile run / walk test was proposed [47, 207]. Muscular strength and endurance could be evaluated through the curls-up, push-up, trunk lift, or the medicine ball throw, all being easy to administer tests. The Flamingo balance test [49] is a reliable evaluation of postural balance and it is suggested since the use of a platform, even if guarantees more accurate results, requires time.

2.4 Study 3

Dual-Task Conditions on Static Postural Control in Older Adults: A Systematic Review and Meta-Analysis

The third research was divided into two phases. In the first, the protocol of the systematic review and meta-analysis was written and published [214] to make the future work as objective as possible. In the second part, the systematic review and meta-analysis was carried on.

The dual-task is the performance of a primary static or dynamic task while simultaneously carrying out an additional secondary task [137]. This concept is adopted with postural control in older adults [139, 140], and it is an important test to prevent the risk of falls [137, 143, 215]. In literature [138, 142] there is a wide variety of secondary tasks such as manual, reaction time, discrimination and decision making, mental tracking, verbal fluency, and working memory tasks. The different types of secondary tasks increase the complexity in the evaluation of postural control [216]. Thus, it became important to evaluate the differences in the effects of the secondary task conditions proposed for older adults. As dynamic tests and complex static posture increase the difficulty of the postural control task [144], the focus of the systematic review and meta-analysis was to summarize and evaluate the secondary task effects on static surface conditions and to contribute to the development of SOPs to study static postural control in healthy older adults.

The systematic review and meta-analysis adopted PRISMA statement [163]. The protocol was registered in PROSPERO (registration number CRD42018116597) and published [214]. PICOS eligibility criteria were followed. Healthy older adults (60 years if age or older) were included. Related to the intervention, studies were included if participants performed the evaluation on a static surface, with parallel feet, with eyes open and the single task was a postural control task. Comparison was between a single task against a secondary task condition. The only outcomes considered were the sway area and path length. Original, peer-reviewed studies (study design) were included.

Studies were collected from the electronic databases PubMed, Web of Science, and Scopus, published until July 29th, 2019. Terms like dual task, double task, secondary task were matched with the Boolean operator ("AND" and "OR") with terms such as postural control, postural stability, postural sway and elderly, old adults, and aging. Duplicates were searched with EndNote (EndNote version X8; Thompson Reuters, New York, NY) and two investigators (not blinded to the content, title, authors and affiliations) performed the selection process by title, abstract, and full-text. A third investigator took the final decision if there was disagreement between the two investigators. Lead author, year of publication, type of study, sample size, participants' age (range, mean and standard deviation), gender, cultural background, education and physical or sport activities practiced, objective of the study, single task technique, dual-task technique, and influence of the dual-task condition relative to the single task were extracted from any section of the manuscript (also from the graphs) and inserted in a Microsoft Excel® (Microsoft Corp., Redmond, WA) spreadsheet. The corresponding author of the manuscript was contacted if the data were not suitable for the meta-analysis before the exclusion of the study. The effect size for the meta-analysis was calculated through the package metafor of the software R (version 3.5.3, Murray Hill, NJ) and to evaluate it, sample size, mean and standard deviation were adopted. A random effect model was adopted and if a study had different secondary tasks conditions, a separate effect size was calculated. The approach of Hedges and Olkin [217], which is an extension of Glass' method [218] was adopted for the meta-analysis. Cohen's d was calculated for all major outcome variables in every study. The single task was considered as the control task for postural control. Cochrane's Q and the I^2 were calculated to evaluate variability across the studies included. A regression for the moderator analysis was also performed comparing secondary task conditions divided in groups (manual task, reaction time task, discrimination and decision-making task, mental tracking task, verbal fluency task, working memory groups, or an additional category named "other") according to a classification previously proposed [138]. The PEDro scale was adopted for the risk of bias assessment [219]. In the risk of publication bias, the funnel plot was used to visually and geometrically evaluate the studies [220].

A total of 66 manuscripts were included in the systematic review, while only 18 studies (with 34 effects) were used for the meta-analysis. The methodology quality of the studies was low (score 3.8 of 10 of the PEDro scale) while no presence of the file-drawer problem (Kendall's Tau=0.13, p=0.33) was for the influence of publication bias.

A significant mean effect t size of d=0.24 [p=0.02, SE=0.1; confidence interval (0.04, 0.44)] was detected in the meta-analysis with high levels of heterogeneity, as demonstrated by Cochrane's Q [Q (df=27) =80.84, <0.0001] and I^2=69.05, which represents substantial heterogeneity. The moderator analysis showed no effect of the measure adopted in the single task condition (Z=1.34, p=0.18), explaining 7% of the residual variance. It revealed a significant difference for what concerns the measures used in the secondary task condition, Q_M(df=5)=14.74, p=0.01, accounting for the 38.22% of variance. Specifically, the studies involving "other" tend to improve postural control (Z=2.64, p=0.008). The different secondary tasks detected are summarized in table 3.

Table 3. *Dual task condition information and authors that used this task*

Dual-task	**Brief description of the Dual-Task condition**
Reaction time task	
simple reaction time task	Verbally respond to auditory stimuli, randomly administered with different times in-between; Verbally respond to a stimulus; Press a button whenever visual or auditory stimuli
go/no reaction time task	Verbally respond only to the high-pitched stimuli with the word "top" ignoring the low-pitched auditory stimuli
choice reaction time task	Respond with different words for high- or low-pitch sound; the digits 1 to 3 had to be identified between 22 digits
inhibition reaction time	Press a button to a go signal given through a LED unless they heard a 'stop' tone through the headphones [221]
probe-reaction time task	Verbally respond to the illumination of a red light located in the centre of a light display unit
Other	
	Identify vertical lines; identify letters and words; force matching task; cell phone task (conversation, dial, listening); identify auditory stimuli

Mental tracking tasks	
counting backward	Counting backward with the numbers two, three or seven
arithmetic task	Solve simple mathematical problems
sequence task	A series of 33-digit numbers. They had to keep track of a single digit within this sequence and to mentally count and sum the occurrence of this digit in the number sequence
Discrimination and decision-making task	
Judgment of Line Orientation task	Pick the 2 numbers that correctly identify the orientation of the lines in an array of lines numbered 1 to 11 set at different orientations, and above the array were 2 unnumbered lines set at the same orientation as 2 of the numbered array
Stroop test	Read 3 tables, 2 tables present the congruous condition (the names of colours are printed in black ink; the names patches with the colours), 1 table present the incongruent condition (the names of colour printed in different colour ink). Name the colour of the ink instead of reading the word; Identify the tone pitch (high or low) ignoring the played word itself
Manual tasks	
	Hold in each hand 2 sticks with interlocked rings at the end, steadily, not to let the rings touch each other [222]; hold a 54.3 cm wooden tray that contained 3 empty foam cups; hold a wooden tube with a table tennis ball inside with both hands; keep a tennis ball contained on a lipped serving tray holding the tray with both hands; flexion and extension both index fingers so that each finger reached its max flexion coincident, the first 8 s with a metronome and after continue to tap alone; the motor focal task consisted in bilaterally performed a 10% maximal voluntary contraction

Memory task	
n-back task	Repeat the digit 0 (0-back), 1 (1-back), 2 (2-back) or 3 (3-back) cycle before of a series of digits successively presented and the number of correct items until the first error
backward digit recall task	Recall backward digits of sequences of 3, 4, and 5 digits (including 0) and within each sequence
digit 2-back task	Indicate a target if a presented digit was identical to the 1 shown 2 steps back in the sequence in a series of 2 digits ranging between 0 and 9
n-back task with words	The 1-back or 2-back has been proposed with words in a series of words presented via headphones
2-back task spatial version	A dot appeared in 1 of 8 locations of a 3x3 grid and indicate a target if a location of the dot was identical to the one shown 2 steps back in the sequence
Brooks' task	Spatial Memory: spatial sentences. The first step was "In the starting square insert 1". Subsequent sentences said to place the number 2 in a square to the right/left/up/down from the previously filled square and so on; Non-spatial Memory: like the previous version but using quick, slow, good and bad.
memory attention-demanding task	Perform a verbal guided multi-step translation on a 3x3 grid (move step by step to the right, or to the left, or backward, or forward) and remember the new localization on the grid
digit memory test	Memorize of a 1 digit string. The difficulty of the test has been tailored in 1 trial in order to obtain a task requesting the same attentional cost [223].
word memory tasks	Memorize and report at the end of the trial, as many words as possible introduced every 2 s, coming from an audiotape
Verbal tasks	
	Talk with the test administrator; sentence completion; repeating a number aloud task

In the protocol review of *study 3*, published before the second part of the work, the procedure was described while in the literature review and meta-analysis, SOPs were created. Generally, the trend noted was the worsening of the static postural stability during the execution of a secondary task. The Stroop test prove to be one of the most challenging condition while the arithmetic tasks, conversely, seems to improve the postural control. The systematic review highlighted important limitations related to the physical, cognitive, cultural and social background of the participants, a wide variety of secondary task conditions adopted and a possibility of bias due to indications given by the investigators to the participants. Consequently, SOPs were proposed. Regarding the physical, cognitive, cultural and social background of the participants, active older adults may present postural control similar to that of young adults [224]. From a cognitive perspective, the intelligence quotient may be an influencing factor during the dual-task execution [225] as the genetic backgrounds [226], and anxiety level [227]. The second point to consider when the dual-task is performed is the choice of the secondary task and the choice to adopt categories should be avoided due to the structure of each task that presents elements of other tasks, as well. Therefore, it is important to propose a specific task and not a category. The final point to consider is the instruction given to the participants by the investigators, indeed, the prioritization of the task influences the results [228]. Furthermore, it is important to consider whether any aspect of the tasks in a dual-task setting should be performed aloud or silently, because all the tasks performed using audible voice could be influenced by respiration [229].

2.5 Study 4

The execution of the Grooved Pegboard test in a Dual-Task situation: A pilot study

The GPT is a test adopted to evaluate manual dexterity [230] which is an important aspect of executive functions [231]. It is also an important test to evaluate neurological and behavioural functions [232]. The GPT is included in the NIHTB® for the Assessment of Neurological and Behavioural Function [232] and it presents good reliability and validity [230]. The GPT is influenced by different factors such as gender [132-134] and education [132, 135]. It should be interesting to understand if other factors could influence the time to complete this test. Because different kind of secondary tasks influence differently the performance of a primary task [233], it was studied how the GPT was influenced by a secondary motor or cognitive task.

Healthy (i.e. no injuries or major problems in their upper limbs, no assumption of drugs or medication that could affect the neuromuscular or cognitive function) and right-handers [selected through the Edinburgh Handedness Inventory (Short Form) test [234]] participants were selected. A final sample of 31 young adults [20 man and 11 women; (mean) age (Standard Deviation): 27.7 (2.5) years; height: 168.7 (8.7) cm; weight: 66.6 (13.1) kg] were retained for investigation. An informed consent to take part in the research was signed by the participants before the study and no payment was provided for participation. The Bioethics Committee of the University of Palermo approved the project (number: 11/2020. Appendix 1), the Helsinki Declaration and the European Union recommendations for Good Clinical Practice were followed. The principles of the Italian data protection were guaranteed.

Data were collected in the same environment and the session was 30 minutes long lead by the same investigator. Before the administration of the tests, participants were informed about the protocol and filled a questionnaire (information on their physical, cognitive and social background were collected). The GPT (Lafayette Instrument, USA) has an easy to adopt protocol [230, 235] and the test consists of placing keyhole-shaped pegs one by one, using only one hand, into 25 holes in a 5-by5 grid, with different keyhole orientation. A total of 10 GPT with a 1-minute rest between each test were performed. The evaluation consisted of 8 GPT to evaluate the training curve, one GPT associated with a cognitive task (serial three test), and one associated with a motor task (finger tapping test). The secondary tasks were administered in a random order. The GPT was previously explained while the secondary tasks are described below:

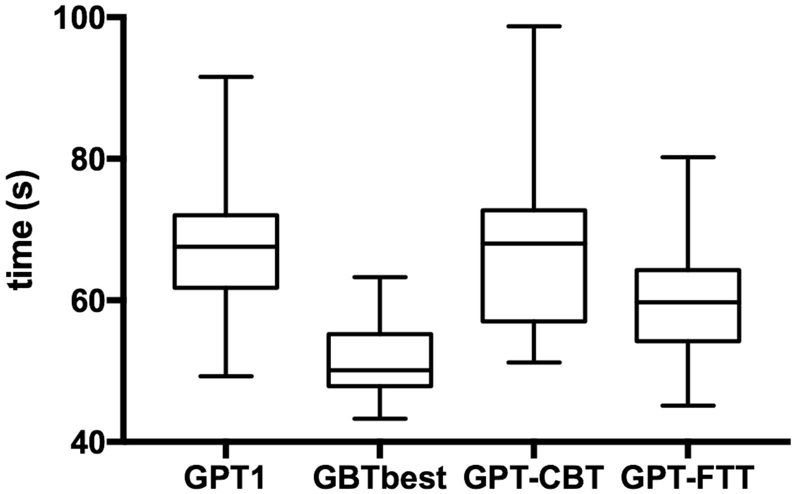
-the "*serial three test*" was chosen as cognitive secondary task and it consists of counting aloud backwards by three, until the end of the experiment [226].

-the "*finger tapping test*" was chosen as motor secondary task. It consists in tapping a surface with the forefinger during the execution of the test [236]. It is useful to evaluate motor speed [237].

The statistical analysis was performed through GraphPad Prism 8.0 for Windows (San Diego, California, USA) and the significance level was set at $p<0.05$. The best and the first GPT were retained for investigation for the first 8 tasks. The normality of the distribution was assessed through the Shapiro-Wilks test with α set at 0.05. The sample size was determined *at-priori* through G*Power software (vers. 3.1.9). The Friedman test was adopted to evaluate the differences across conditions and to evaluate the training effect across the first 8 GPT. To study the training effect between tasks a Dunn's multiple comparisons test was computed.

The Friedman test and the Dunn's test identified a significant difference between the first and the best GPT ($p<0.0001$). Significant difference was also between the best and the GPT executed with the cognitive task ($p<0.0001$), with a mean additional time of 13.9 sec was required to complete the test in dual-task. Similarly, a significant difference was also detected between the best and GPT executed with the secondary motor task ($p<0.01$) which resulted in a mean additional time of 7.1 sec required to complete the test in the dual-task setting. Differences were noted also between the first and the GPT associated with the finger tapping test ($p<0.01$) (GPT first was 8.6 sec slower) (Figure 1).

Figure 1. *Graphical representation of the GPT performed with and without a secondary task. Figure taken from the paper: [238]*



GPTbest: GPT with the best performance after 8 repetitions; GPT-CBT: GPT in combination with the counting backward task; GPT-FTT: GPT in combination with the finger tapping test

A difference was also present between the GPT associate with a cognitive task and the one proposed with a motor task with a difference of 7.1 sec ($p<0.05$). A significant difference was found between the first and GPT after 3 trials with the time to complete the test after 8 trials. Differences were detected also after the GPT at the second trial and at the fifth trial again with the last trial of the manual dexterity test. *Study 4* highlighted the necessity to perform a further investigation on the topic GPT in dual-task. The findings of the study are in line with a previous study [239], in which the addition of a secondary task worsened the pegboard test performance. The addition of a cognitive oriented task resulted in worse performance compared to the addition of a motor oriented task, similarly to previous studies [137, 143, 240]. In conclusion, the GPT performed in dual-task is a feasible test to deeply evaluate manual dexterity and cognitive functions.

2.6 Study 5

Time spent on the smartphone does not relate to manual dexterity in young adults

In the literature [132, 133, 230] and in in the user instructions (Lafayette Instruments, USA) exists different normative data for the GPT. The most recent study on this topic was published on 2011 [230]. Thus, the ever-increasing time frequency of smartphones and related mobile applications, and social media should have an impact on daily life [241]. This changing of everyday life must be considered in evaluating manual dexterity. Because young adults spend more time on the smartphones compared to older adults [242], it was hypothesised that the normative data related to adolescents and young adults should be to update. For this reason, the purpose was to evaluate how time spent on a smartphone impacts GPT execution in young adults.

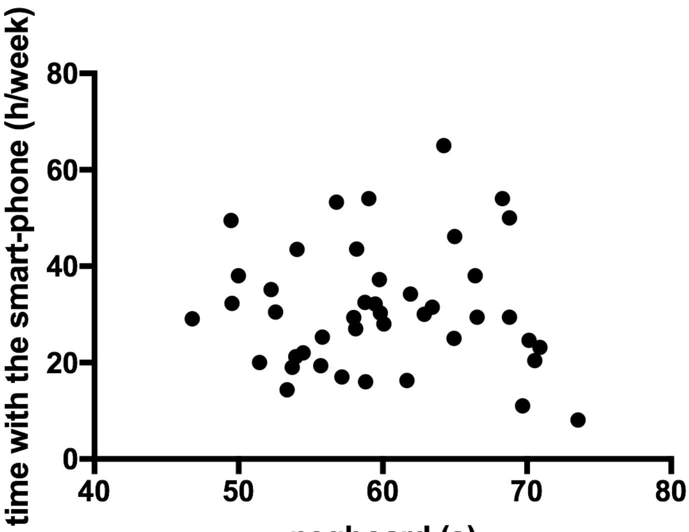
Healthy (i.e. no injuries or physical problems in their upper limbs and neurological disease) young adults (19-24 years old) were included for investigation in order to reduce the influence of cultural and education level [243]. Participants, before the study, were informed about the testing procedure and they provided a written consent to take part in this research and allowed the use of their data. Participants were not financially compensated. The study was carried out in accordance with the ethical standards of the Declaration of Helsinki and it was approved by the Bioethics Committee of the University of Palermo (ID: 19/2020. Appendix 2). A total of 41 (25 women and 16 men) participants were included; a power analysis with G*Power software (version 3.1.9) at 0.80 revealed a minimum sample required of 26 participants. The mean age (standard deviation) was 20.7 (1.5) years; height 169.2 (28.7) cm; weight was 69.3 (13.9) kg.

Participants completed a single session of about 30 minutes. The session comprised the completion of a questionnaire (with questions related to age, gender, height, weight, handedness and weekly time spent on smartphones) and one GPT repetition. The Edinburgh Handedness Inventory (Short Form) was adopted to determine and define the dominance of the upper limbs [234]. The time spent in a week with the smartphone was assessed through the phone itself. The testing procedure for the GPT was previously described.

The statistical analysis was performed with GraphPad Prism 8.0 (San Diego, California, USA). The normality of the data was evaluated through the Shapiro-Wilks test with α set at 0.05. Difference between gender was evaluated through the t-test. The correlation between the time to conclude the GPT and the time spent with the smartphone was tested through a Pearson correlation analysis. The p value was set at 0.05.

Data related to the time spent on the smartphone and the GPT were normally distributed. No significant difference was observed across gender (p=0.87), even if, generally, men spent more time on the smartphone compared to women [32.0 (12.6) vs 31.3 (13.2) h/week, for man and woman, respectively]. No difference was also observed regarding the GPT execution time [58.9 (7.3) vs (61.8 (6.0) sec, p=0.20, for woman and man, respectively]. The correlation test for the GPT and the time spent on the smartphone was not significant (r=0.044, p=0.78) (Figure 2).

Figure 2. *Correlation between GPT (sec) and weekly time spent on a smartphone (h/week) (p=0.78). Figure taken from the paper: [244]*



s: seconds; h: hours

Study 5 suggests that the time spent on the smartphone does not influence the time adopted to complete the GPT in young adults. The study, consequently, indicates that the normative data previously proposed [230] are still valid. These results could be explained by the fact that motor skills and cognition (in young adults) present differences in the activation zone of the cerebellar lobes [245, 246]. Moreover, the literature on this topic is contradictory [247, 248] suggesting further investigations in this field in the future. To be considered in the future it is also that the study is for a specific population (young adults) and adolescents, that nowadays have been growing up and are very frequently with the smartphones in their hands, and older adults, that could be more influenced by their working and cultural background than the time spent on the smartphones, were excluded.

2.7 Study 6

Influence of the stress level on the execution of the Grooved Pegboard Test

Mental fatigue generally impairs cognitive processes [249] such as attention tasks do [250]. It has been noted that the practice of mindfulness-based meditation, Qigong, Tai Chi, martial arts based on controlling the respiration and of the body, reduces blood pressure, stress and anxiety, and improve mental health outcomes, functional balance, and immune function [251, 252]. Similarly, yoga appears to have inhibitory effects on physiological stress [253]. The monitor of the heart, such as the Heart Rate Variability, provide information related to the integrity of the autonomic nervous system [254, 255] and it is possible to obtain information about the complex network that exists between the sympathetic and parasympathetic systems [256] but also to monitor anxiety [254, 257]. Interesting, the heart variability is related to cognitive functions [258, 259]. For these reasons, it is interesting to study the correlation that exists between stress parameters (evaluated through the heart beat), control of the breath and GPT results.

A total of 114 participants, [67 females, 47 males; mean (standard deviation): 23.8 (7.5) years (24.3 (7.5) and 23.4 (7.6) years for women and men respectively), height was 172.5 (19.3) cm, and weight of 70.7 (15.0) kg], were recruited and all of them completed the testing session. Participants were excluded if they presented injuries or physical problems in their upper limbs. The study was carried out following the ethical standards of the Declaration of Helsinki and it has been performed by the University of Palermo (Italy) and the Lithuanian Sports University (Kaunas, Lithuania). Before the study, each participant was informed about the testing procedure, the benefits, and the risks of the study. Written consent to take part in this research and allowed the use of their data was asked to the participants. No payment was provided for participation. A single session of data collection of about 30 minutes was performed in which participants had to perform a stress level test, the GPT, and a breathing exercise for relaxation. Participants' personal information such as age, gender, height, weight, and handedness [the Edinburgh handedness inventory short form [234]] were recorded. After this, participants were divided into two groups. Participants of group 1 did the following procedure: stress level test 1, GPT1, three minutes rest, GPT2, stress level test2, three minutes of breath relaxation, GPT3. Group 2, instead, followed the following procedure: stress level test1, GPT1, three minutes of breath relaxation, GPT2, stress level test2, three minutes of rest, GPT3. At the end of the testing procedure, participants performed two handgrip tests to evaluate maximal voluntary contraction. Stress was evaluated in a seated position, with the left hand on the desk attached to the SmartPulse device (Medicore Ltd., Korea) connected to the computer. During the breathing exercise participants performed slow and deep abdominal breathing (six cycles/min) with prolonged exhalation and during the exhalation, participants had to try to relax as much as possible, also from a physical point of view.

The statistical analysis has been performed through the program GraphPad Prism (Vers. 8.0). The normality of the data was evaluated through the Shapiro-Wilks test with α set at 0.05 and it has been established that the data were not normally distributed. Data were presented as means and standard deviations. The correlation between the GPT at baseline and age, height, weight, and handgrip were evaluated through the Spearman test. The same statistical test was adopted to evaluate the correlation between the GPT baseline and the physical stress, the mental stress, the stress resistance, the stress score, and the HR frequency. The Friedman test and the Dunn's was performed between the GPT baseline and its time evaluated after rest and after relaxing exercise. The Mann-Whitney test was performed between physical stress pre and post in group 1 and 2, and between mental stress pre and post in both groups. The same statistical analysis was performed with the rest without indications. The p value was set at 0.05.

In the results for the Spearman test, GPT evaluated at baseline presented a significative ($p<0.05$) correlation with age (r= -0.0207; 95% confidence interval (CoF)= -0.38 to -0.01), height (r = 0.217; 95% CoF= 0.02 to 0.39), weight (r = 0.21; 95% CoF= 0.02 to 0.38) and handgrip (r= 0.213; 95% CoF= 0.02 to 0.39). No significative ($p>0.05$) correlation was found between the GPT at baseline and physical stress (r=0.135; 95% CoF=-0.06), mental stress (r=-0.0917; 95% CoF=-028 to 0.1), stress resistance (r=-0.104; 95% CoF=-0.29 to 0.09), stress score (r=0.0553; 95% CoF=-0.14 to 0.24), and HR (r=-0.0164; 95% CoF=-0.21 to 0.17). The Friedman and Dunn's post-test showed a $p<0.01$ between GPT baseline and

GPT rest, p<0.01 between GPT baseline and GPT relax and a p>0.05 between rest and relax. Group 2 and a p<0.01 for GPT baseline and rest, a p<0.0001 between GPT baseline and GPT relax and a p>0.05 between GPT rest and relax. Results related to the stress level are summarised in Table 4 (physical and mental; stress score and HR).

Table 4. *Results related to the physical stress, mental stress, stress score, HR for group 1 and 2 and p value after the Mann-Whitney test.*

	Physical stress	**Mental stress**	**Stress score**	**HR**
Group 1				
Baseline	37.1 (24.5)	47.2 (34.2)	54.2 (14.4)	88.3 (18.3)
Rest	36.3 (24.7)	43.8 (35.3)	54.9 (12.5)	84.5 (20.6)
Delta / p value	0.8 / 0.9	3.4 / 0.5	-0.7 / 0.7	3.8 / 0.2
Group 2				
Baseline	35.5 (25)	48.8 (34.2)	51.2 (13.2)	88.9 (17)
Respiration	33.4 (27.9)	47.8 (36.1)	53.7 (18.2)	82.8 (18.2)
Delta / p-value	2.1 / 0.3	1 / 0.7	-2.5 / 0.7	6.1 / 0.03

The findings suggest that a breath relaxation technique does not influence significatively the time to complete the GPT and how physical stress increases the time to complete the GPT while high mental stress, stress resistance, and HR decrease the time to complete the test. For this reason, it is suggested before the GPT, to perform a slow and deep abdominal breathing with prolonged exhalation. Even if no statistical differences were noted, breath relaxation decreases physical stress and HR importantly than to do nothing, such as the velocity to complete the GPT, this could be explained by the role that the anterior cingulate cortex has in the interface between cognition and emotion [258]. Limitations of the study are related to the specific sample (only young adults) and the duration of the intervention (that could be longer). Future studies should have to include adolescents, adults and older adults such as active and sportive people. Furthermore, other studies could adopt a longer intervention period to obtain clear results and with effects prolonged in the time.

Chapter 3. Discussion

The three reviews highlighted that in the scientific literature there is a lack of SOPs, standard protocols, or guidelines for the evaluation of different populations with field tests such as the vertical jumps in adolescents, the physical fitness assessment in visual impaired people practicing goalball, or the dual-task setting in older adults. It was noted in the three studies a vast variety of testing protocols, methodologies, measurement devises and tests to evaluate the same or a similar component (Table 5).

Table 5. *Review characteristics*

	Typology	***Topic***	***Method***	***SOPs***
Study 1	Review	Vertical jumps in adolescents	Partially PRISMA	No, proposed in the manuscript
Study 2	Scoping review	Goalball in visual impaired people	PRISMA-ScR	Partially presents in the literature
Study 3	Review / meta-analysis	Dual-task in elderly	PRISMA	No, proposed in the manuscript

Consequently, this lack of SOPs (Table 6) reduces the possibility to compare the results between studies but also between teachers (*study 1*), coaches (*study 2*), or doctors (*study 3*) of different sport teams, schools, or clinics. Furthermore, the development of normative data, important tool to monitor the health level of a population, results compromised or influenced by the procedure or the instrument adopted. Also compromised are future communications and sharing of data, as much as the possibility to analyse the results with a quantitative study (meta-analysis). This limit importantly the applicability of some testing procedures and the quality of the evaluation. Consequently, it is interesting to elaborate this topic deeply in the future, with a particular attention of field testing methods as this thesis tried to do. The reason to focus on field tests is because this kind of evaluation is usually easier to administer, faster and cheaper compared to laboratory tests [97]. The testing methods studied (countermovement jump and squat jump, sit and reach test and shoulder stretch, 1-mile walk/run test, the curl-up and push-up, two-point skinfold thickness, and Flamingo balance, dual-task setting, and the GPT) were, indeed, easy to administer, cheap, and that require few time to be completed making them ideals for a health-promotion contest.

The creation of SOPs for the countermovement and the squat jump tests (*study 1*) was composed by the description of the jumps phases, the standardization of the warm-up, and information related to the device to adopt. This could facilitate the evaluation and the data normalization for muscle force and power of the lower limbs, especially in the health context. Also a field battery as the Brockport Physical Fitness test with specific and standardized tests, suggested in *study 2* wants to help the community to perform a higher quality evaluation. This could also help the coaches to work with comparable data and consequently to monitor the training in the best way possible. *Study 3* wanted to provide clarifications related to the dual-task evaluation. The findings could help to adopt standard secondary tasks condition in intervention studies, but also in rehabilitation programs.

Table 6. *Findings of the reviews of literature*

	Findings	**SOPs proposed**
Study 1	Different methodologies were adopted in the literature, consequently SOPs for these two vertical jumps do not exist	Standardization of the start, push-off, toe-off, apex of the jump, landing, warm-up, hands position, number of jumps, equipment
Study 2	Different tests were proposed to evaluate goalball athletes and practitioners	The Brockport Physical Fitness test with standardized tests could be adopted as SOPs in goalball.
Study 3	The main effects of dual-task on static postural control are confused	Bipedal static postural control was worsened by the Stroop test while the arithmetic tasks improved it.

Related to the original researches (Table 7), *study 4* detected the different influence of a motor and a cognitive secondary task on the time to complete the GPT. These results are confirmed by the literature in postural control tasks [137, 143, 240] and for the upper extremities [260]. Because this trend is confirmed, the

GPT could become a future primary task to study dual-task situations. *Study 5* confirmed that the update of the normative data for the GPT is still not required even if since the introduction in 2007 of the Apple's iPhone, a device able to replace computers and laptops [242] people started to use frequently their fingers to use the applications. Probably more time is required to influence importantly the nervous system, consequently, in the future similar studies should have to be performed again. During *Study 6* was investigated if the time to complete the GPT was influenced by the stress level and if a breathing exercise proposed to reduce the stress was useful before the execution of the manual dexterity test. In conclusion, stress does not influence significantly the GPT execution even if it has an effect on the final time. Although the field investigated during these three years is reduced to a few tests and specific populations, it is clear that in the Sports Sciences it is necessary to follow standard protocols in the evaluation of physical fitness, especially for those populations at risk such as children, adolescents, older adults and people with specific needs.

Table 7. *Original studies characteristics*

	Tipology	***Topic***	***SOPs***
Study 4	Pilot study	Dual-task on manual dexterity	GPT was influenced more by the cognitive than the motor task
Study 5	Experimental study	Smartphone on manual dexterity	The time spent on the smartphone does not influence the GPT
Study 6	Experimental study	Stress on manual dexterity	Stress does not significantly influence the GPT

The six studies included in this thesis are an example of the work that could be done in the future to standardize the testing procedures, normalize the data making scientific literature comparable.

3.1 Personal experiences with the reviews of literature

Performing literature reviews was useful to learn how to use this important tool for learning about a topic and for writing a study accurately and in detail. Between the different methods, in general, the execution of a systematic review, for the described structure procedure [261], reduces the bias [262]. Furthermore, the advantage of adopting a systematic review, instead of other review typology, is due to more objective appraisal of the available evidence [263]. Having written different types of reviews helped me understand the differences between the methodologies and consequently the importance of adopting one type instead of another.

The reviews performed and included in the thesis were conducted in agreement with the principles outlined by PRISMA statement [163]. Consequently, before the study of the systematic review, the protocol was written (*study 1 and 2*) and, when possible (*study 3*) it was previously registered in PROSPERO and published [214]. The creation of the protocol required different steps in which I participated actively in accordance with the co-authors. All parts and aspects of the procedure were decided in steps comparing the methodology and theories with the literature related to the topic. In this step-by-step process, the initial idea was improved and elaborated until the protocol adopted in the reviews was defined and approved by the co-authors. Important aspects considered were the eligibility criteria and the search process procedure. As suggested by PRISMA statement [163], PICOS was adopted in the reviews included in this thesis. For the three reviews a lot of attention was dedicated to terms adopted and their combination because a complete search strategy determines the comprehensiveness of the review [262]. As the literature suggests [262], the search was performed by two investigators, who worked independently of one another, due to the errors that only one person could commit such as not taking account of relevant studies. In all the reviews, abstracts and the gray literature were excluded to reduce the effect of publication bias and to avoid the results were influenced because not always this kind of literature is peer-reviewed [262]. Always about the inclusion and exclusion criteria, even if literature [262] highlights that limiting the studies on the language reduces the amount of studies included, it was decided to include only English studies to facilitate full understanding.

Related to *study 3*, in which data were collected for the meta-analysis execution, as suggested by the literature [262], investigators were contacted to obtain data not published. The meta-analysis was performed as a useful instrument to examine the effect of a secondary outcome of other independent studies [263]. Considering that the quality of the methods used in included studies such as the eligibility criteria adopted and the bias detected influences the validity of the meta-analysis [263], the screening process was performed carefully considering PICOS components [262]. Techniques such as the I^2 test, to quantify the heterogeneity, the random effect analysis, the subgroup analyses and meta-regression were adopted. The funnel plot was also used and the results interpreted according to the guidelines of Crowther and colleagues [262]. This process helped me to understand the importance of the performance of appropriate statistical analysis and the attention that have to be adopted in the production of a manuscript to obtain high quality studies. Furthermore, having adopted the PRISMA statement made me understand the importance of writing the protocol before the study both, for a review or an experimental study. Only in this way it is possible to perform a study as objectively as possible without being influenced by the findings.

For *study 1*, the idea was proposed by Prof. Bianco and Prof. Karsten, I was actively interested in each part of the manuscript and also corresponding author. The manuscript was published. For *study 2*, the idea, physical fitness in goalball athletes, was proposed by Prof. Battaglia. The study was performed with Dr. Aurea who used the data also for her master's dissertation. The final version of the manuscript was approved by all authors and published. *Study 3* is about dual-task activities in older adults. I was actively part of each part, from the search of the articles on the electronic databases to the screening of the studies against the eligibility criteria, from the analysis of the studies collected, to the risk of bias assessment [the PEDro scale and the Egger Regression Test [220] were adopted]. Following this long process, the meta-analysis was performed with the collaboration of Dr. Gentile, a fellow Ph.D. student. The final version of the manuscript, approved by all co-authors, was submitted by me to a peer-review Journal and published.

Unfortunately, the sample of the reviews is specific: in one review only adolescents were taken into consideration, in another only older adult, or only people with visual impairments. The decision to consider only one specific population was due to the wide literature that existed on the topic. Another important limitation is related to the impossibility to perform systematic reviews and meta-analysis on all the revision of the literature because of the differences that existed between the articles considered. Future studies should have to consider these limitation as feedbacks.

3.2. Personal experiences with the original articles

From the principles learned while performing the literature reviews, the protocols of the experimental studies were written before the studies were carried out. Related to *study 4*, the decision to perform a pilot study was taken because this kind of investigation is useful to understand if the test and the treatment can be proposed correctly for the experimental study [169]. Moreover, it shows how to coordinate the sample in the most appropriate way (from an ethical point of view and respecting privacy) and to manage the data [through well-structured Microsoft Excel® (Microsoft Corp, Redmond, Washington) documents], thereby showing to me a great deal about statistical analysis. The method was planned and performed in *study 5 and 6* in a similar way of *study 4*. In the three *studies (4, 5 and 6)*, I adopted the program for statistical analysis GraphPad Prism 8.0 for Windows (San Diego, California, USA) to perform the Shapiro-Wilks test to study if the data were normality distributed and consequently to adopt one statistical test instead of another. Indeed, two categories of technique to analyse the data exist: the parametric statistics (based on the assumption that data are normally distributed, that the variance is equal to that of the variable of interest, and that the observations are independent), and non-parametric statistics (if parametric statistics cannot be adopted) [169]. In *study 4*, I adopted the Friedman and the Dunn's multiple comparison test to evaluate differences between the variables (more than two). In *study 5* was also adopted the t-test because two variables were analysed, and a correlation analysis through the Pearson test in which the authors supposed that a linear relationship existed. The Spearman test was adopted in *study 6* (in which a monotonic relationship was hypothesised) and the Mann-Whitney test to detect differences between pre and post intervention in the two groups. Finally, I also understood how to interpret and discuss the findings in the most appropriate way.

The decision to study the GPT come from the period spent in the laboratory of Prof. Enoka. This experience in the United States, in the Colorado University in Boulder's physiology lab, enabled me to learn the basics of research methodology. During the six months, two research projects were followed where I participated actively in building some equipment, data collection, and analysis. The first one was related to manual dexterity and decision making, while the second one was on the effect of trans-electrical stimulation on people with multiple sclerosis. During the two projects, I learned how to project, prepare and manage a cross-sectional study and an intervention study. I also learned to use surface electromyography and the interpretation of the results. During the projects, different field tests were adopted such as postural stability tests, decision making tests, the 6-min walk test, the 20-meters walking test, the handgrip test, and maximal voluntary contraction tests. The first project was published [235] while project two was submitted to an international peer-reviewed Journal. In both studies, the GPT was adopted, an easy to administer, valid, and reliable test to evaluate manual dexterity. This test is useful to evaluate executive functions [231] and, consequently, makes this test particularly interesting to assess different contexts. For these reasons, it was decided to further evaluate this instrument once in Italy.

In Italy, during the second part of the second year, a study was conducted to evaluate the association between the GPT and dual-tasks activities. The study was proposed by me, improved and defined by Prof. Bianco. The study was conducted by Dr. Iacona, a student of the University of Palermo, guided by me. The findings were first used for the dissertation of the student then, the manuscript was written by me and it was checked by all co-authors involved in the study. The study was accepted and published in a peer-review Journal.

After this study, one study was carried on related to the association between the GPT and the time spent on the smartphone. Another one was performed to evaluate the relationship between stress level and time to complete the GPT. The two studies were performed in Lithuania, in the Lithuanian Sports University, under the supervision of Prof. Pajaujiene. In the researches, I proposed the idea that was improved by Prof. Bianco and Prof. Pajaujiene. The evaluation, data synthesis and analysis were performed by me, guided by Prof. Bianco and Prof. Pajaujiene. The manuscripts were written by me and feedback were provided by all co-authors. *Study 5* was accepted and published in a peer-review Journal. *Study 6* is under peer-review in an international Journal. In all the studies performed, Prof. Palma supervised me.

In the original studies, a specific population was considered and this was composed of young or adults. It was decided to test only young adults to limit the confounding effects related to age. Future studies should consider different populations and make specific SOPs according to the characteristics of the sample analysed.

3.3 Ph.D. experience implemented during the three years program

Study 1 was discussed orally during the congress of the "Società Italiana Scienze Motorie e Sportive" (SISMES) 2018 in Messina (Italy) as *study 3* that was presented orally during the congress of the SISMES 2019 in Bologna (Italy). *Study 4* was presented in the 2nd Sport Forum, an International Scientific Conference (Kaunas, Lithuania). A study performed by me with Dott. Landro (a master's degree student), guided by Prof. Bianco and Prof. Karsten, under the supervision of Prof. Palma on functional threshold power of cyclists was presented, always by me, during the online Young Investigation Awards session of the European College of Sport Science (ECSS) conference 2020 (Appendix 2).

The experience on reviews of literature and SOPs allowed me to follow different masters' degree dissertations about performance evaluation in cyclists with field tests, GPT and cognitive functions, goalball and physical fitness, and sitting volleyball and physical fitness evaluation. I also shared my knowledge on PRISMA statement with the masters' students of the University of Palermo in a frontal teaching classroom of Prof. Bianco.

I was the corresponding author of different published studies [264-267] in which I participated with the co-authors for the data analysis and interpretation, the manuscript writing, finalization, and I was responsible for the revisions after the reviewer comments. I also collaborated in different researches [268-271] (Appendix 2). Furthermore, I was a reviewer for different Journals.

Conclusion

Standard Operating Procedures are needed in an international and multidisciplinary context to perform the tests in the same way. Furthermore, the experience gained, made me to understand the importance of creating international and interdisciplinary teams, so that the work is evaluated by different experts from different fields. Only in this way it is possible to have a final work that takes into account the different spheres that make up the whole.

The results from this thesis significantly contribute to the field of Sports Sciences methodology. Firstly, a standardized methodology for the countermovement and the squat jump was proposed, in this way investigators, coaches, and practitioners can use a test that is replicable and can compare the results. Second, a standardized physical fitness test battery was provided for people practicing goalball and underling the importance of the practice of physical activity in people with special needs. In the third point a clarification and guidelines were provided for the secondary tasks influence but also for the test management. The last point it was to provide clarifications on the effect of different secondary tasks (manual and cognitive), the time spent on the smartphone, and the stress level and management on the execution of a manual dexterity test, the GPT.

In conclusion, the work done was useful in introducing SOPs in the field of Sports Sciences and underlining the importance of using previously created, validated and standardized protocols. In all the studies performed it was noted the lack of SOPs and consequently, the thesis provided guidelines even if much more needs to be done to refine these in the coming years.

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Statistical methods for meta-analysis

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Appendix

Appendix 1a. Bioethics Committe approval for study 4

UNIVERSITÀ DEGLI STUDI DI PALERMO
COMITATO DI BIOETICA
D.R. n. 3267 del 09/10/2019

Seduta del Comitato di Bioetica del 25/05/2020
Parere n. 11/2020

Richiesta di parere n. 11/2020

Titolo della ricerca: Destrezza manuale e dual task

Ricercatore Proponente: Prof. Antonino Bianco
Ruolo: Professore associato
e-mail: antonino.bianco@unipa.it

Area di ricerca: Scienze Motorie
Dipartimento: Dipartimento di Scienze Psicologiche, Pedagogiche, dell'Esercizio Fisico e della Formazione.

Ricercatori partecipanti

a. **Ricercatori dell'Università di Palermo**: Antonio Palma, Petrigna Luca (dottorando), Thomas Ewan (ricercatore), Iacona Gaetano Marco(studente) del Dipartimento di Scienze Psicologiche, Pedagogiche, dell'Esercizio Fisico e della Formazione.

b. **Ricercatori Italiani:** Paoli Antonio dell'Università di Padova.

c. **Ricercatori di altre Nazioni:** Pajuajiene Simona University of Lithuanian.

Metodi della ricerca Ricerca con la somministrazione di test standardizzati ad adulti.

Principale obiettivo della ricerca: Valutare l'effetto di un compito cognitivo e motorio secondario sul Pegboard test. Valutare la curva di apprendimento del Pegboard test.

Moduli di informazione per le persone che parteciperanno alla ricerca:

a. Il modulo informativo per la partecipazione alla ricerca è stato presentato? Si
   Il modulo è stato giudicato chiaro e completo? Si
b. Il modulo informativo per il trattamento dei dati personali è stato presentato? Si
   Il modulo è stato giudicato chiaro e completo? Si
c. Osservazioni: --

Componenti del Comitato di Bioetica presenti alla seduta: Prof. Vito Di Marco, Prof.ssa Marianna Alesi, Prof.ssa Alice Pugliese, Prof. Marco Brigaglia, Prof. Pietro Perconti.

UNIVERSITÀ DEGLI STUDI DI PALERMO
COMITATO DI BIOETICA
D.R. n. 3267 del 09/10/2019

Parere del Comitato
Il Comitato di Bioetica, dopo attento esame delle informazioni fornite dal proponente, esprime parere positivo riguardante gli aspetti bioetici della ricerca, **con la prescrizione circa la creazione di un modulo di consenso informato bambini disgiunto da quello adulti.**

The project has been approved by the Bioethics Committee of the University of Palermo, with the prescription about the creation of an informed consent form for children separated from the adult one.

Il Comitato Bioetica si riserva di revocare l'approvazione qualora il progetto non venisse condotto secondo quanto dichiarato nel protocollo di ricerca approvato dal Comitato.
Pertanto, modifiche in qualsiasi punto della procedura o del consenso informato dovranno essere sottoposte nuovamente all'attenzione del Comitato.

Il Presidente del Comitato
Prof. Vito Di Marco

Il Comitato di Bioetica dell'Università di Palermo
Prof. Vito Di Marco (Presidente) vito.dimarco@unipa.it; Prof.ssa Marianna Alesi (Vice Presidente) marianna.alesi@unipa.it;
Prof.ssa Alice Pugliese, alice.pugliese@unipa.it; Prof. Marco Brigaglia, marco.brigaglia@unipa.it;
Prof. Pietro Perconti (Componente Esterno) pietro.perconti@unime.it.

Appendix 1b. Bioethics Committe approval for study 5

UNIVERSITÀ DEGLI STUDI DI PALERMO
COMITATO DI BIOETICA
D.R. n. 3267 del 09/10/2019

Seduta del Comitato di Bioetica del 30 luglio 2020

Parere n. 19/2020

Richiesta di parere n. 19/2020

Titolo della ricerca: "*Studio trasversale per la valutazione dell'influenza del tempo di utilizzo dello smartphone sulla destrezza manuale in studenti universitari*"

Ricercatore Proponente: Prof. Antonio Palma
Ruolo: Professore Ordinario

e-mail: antonio.palma@unipa.it

Area di ricerca: SSD: MEDF/01

Dipartimento: Dipartimento di Scienze Psicologiche, Pedagogiche, dell'Esercizio Fisico e della Formazione.

Ricercatori partecipanti

a. **Ricercatori dell'Università di Palermo:** Antonino Bianco Professore Associato, Antonio Palma Professore Ordinario, Petrigna Luca Dottorando, del Dipartimento di Scienze Psicologiche, Pedagogiche, dell'Esercizio Fisico e della Formazione.

b. **Altri Ricercatori Italiani:** No

c. **Ricercatori di altre Nazioni:** Simona Pajuajiene - Lithuanian Sports University.

Principale obiettivo della ricerca: la valutazione dell'effetto del tempo trascorso su uno smartphone sull'esecuzione della GPT nei giovani adulti.

Metodi della ricerca: Studio trasversale per la valutazione dell'influenza dello smartphone sulla destrezza manuale in studenti universitari di età compresa tra i 18 e i 30 anni. In circa trenta minuti il test verrà concluso e include un questionario per raccogliere informazioni relative all'utilizzo dello smartphone. In seguito, il grooved pegboard test verrà proposto una sola volta.

Il Comitato di Bioetica dell'Università di Palermo
Prof. Vito Di Marco (Presidente) vito.dimarco@unipa.it; Prof.ssa Marianna Alesi (Vice Presidente) marianna.alesi@unipa.it;
Prof.ssa Alice Pugliese, alice.pugliese@unipa.it; Prof. Marco Brigaglia, marco.brigaglia@unipa.it;
Prof. Pietro Perconti (Componente Esterno) pietro.perconti@unime.it.

Moduli consenso informato e trattamento dei dati personali per le persone che parteciperanno alla ricerca:

a. Il foglio informativo per la partecipazione alla ricerca e al trattamento dei dati personali è stato presentato? SI
Il foglio è stato giudicato chiaro e completo? NO.
b. Il modulo di espressione di consenso alla partecipazione alla ricerca è stato presentato? SI
Il modulo è stato giudicato chiaro e completo? NO
c. Il modulo di espressione di consenso al trattamento dei dati personali è stato presentato? SI
Il modulo è stato giudicato chiaro e completo? NO

Osservazioni:
Nei moduli a), b) e c) occorre inserire il titolo della ricerca.
Si invita ad integrare i dati e a ritrasmettere i modelli modificati alla segreteria del Comitato, per l'acquisizione agli atti della richiesta del parere.

Componenti del Comitato di Bioetica presenti alla seduta:
Prof. Vito Di Marco, Prof.ssa Marianna Alesi, Prof.ssa Alice Pugliese, Prof. Marco Brigaglia, Prof. Pietro Perconti.

Parere del Comitato

Il Comitato approva la ricerca, sotto il profilo bioetico, con la seguente annotazione: specificare le modalità di restituzione e divulgazione dei risultati della ricerca (es. riunioni, convegni, pubblicazioni su riviste scientifiche), escludendo la possibilità di invio mail ai partecipanti volontari.

The project has been approved by the Bioethics Committee of the University of Palermo.

Il Comitato di Bioetica si riserva di revocare l'approvazione qualora il progetto non venisse condotto secondo quanto dichiarato nel protocollo di ricerca approvato dal Comitato.
Pertanto, modifiche in qualsiasi punto della procedura o del consenso informato dovranno essere sottoposte nuovamente all'attenzione del Comitato.

Il Presidente del Comitato
Prof. Vito Di Marco

Il Comitato di Bioetica dell'Università di Palermo
Prof. Vito Di Marco (Presidente) vito.dimarco@unipa.it; Prof.ssa Marianna Alesi (Vice Presidente) marianna.alesi@unipa.it;
Prof.ssa Alice Pugliese, alice.pugliese@unipa.it; Prof. Marco Brigaglia, marco.brigaglia@unipa.it;
Prof. Pietro Perconti (Componente Esterno) pietro.perconti@unime.it.

Appendix 2a. List of discussed abstracts

Systematic review:
countermovement and squat jump testing methods
in the context of public health examination.
Reliability and feasibility of current testing procedures

UNIVERSITÀ DEGLI STUDI DI PALERMO

Luca Petrigna, PhD student

Joint Program in Health Promotion and Cognitive Sciences
University of Palermo, Italy
in partnership with
Lithuanian Sports University, Lithuania

luca.petrigna@unipa.it

LITHUANIAN SPORTS UNIVERSITY

Oral presentation during the congress of the SISMES 2018 in Messina (Italy)

Dual-task conditions on static postural control in older adults:
a systematic review and meta-analysis

Luca Petrigna, Ambra Gentile, Diba Mani, Simona Pajaujiene, Tobia Zanotto, Ewan Thomas, Antonio Paoli, Antonio Palma, Antonino Bianco

UNIVERSITÀ DEGLI STUDI DI PALERMO

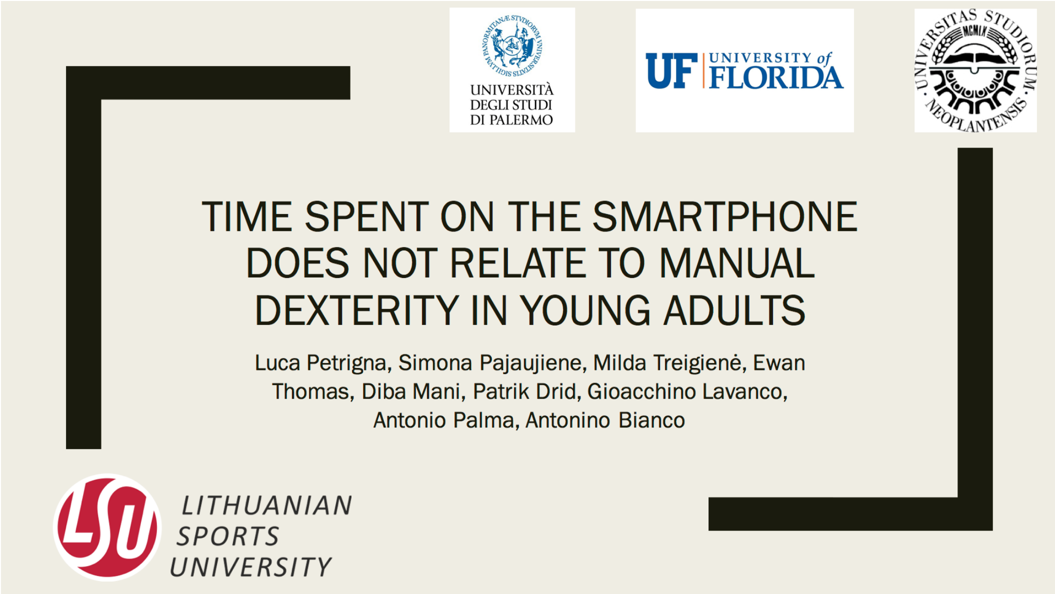
Luca Petrigna, PhD student

Joint Program in Health Promotion and Cognitive Sciences
University of Palermo, Italy
in partnership with
Lithuanian Sports University, Lithuania

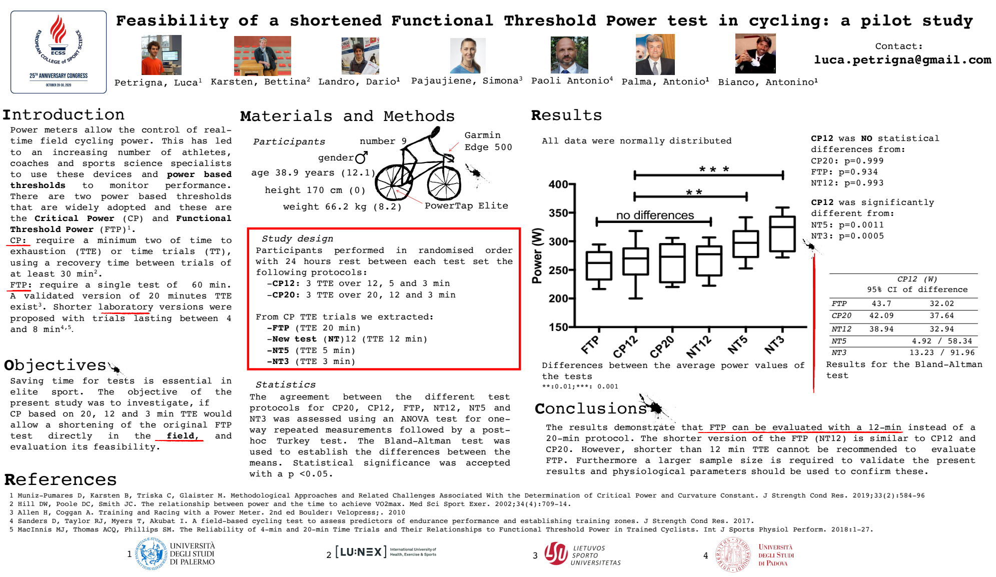
luca.petrigna@unipa.it

LITHUANIAN SPORTS UNIVERSITY

Oral presentation during the congress of the SISMES 2019 in Bologna (Italy)



Oral presentation during the 2nd Sport Forum, an International Scientific Conference 2020 in Kaunas (Lithuania)



Poster presentation for the Young Investigation Awards session of the European College of Sport Science (ECSS) conference 2020. Online

Appendix 2b. List of publications

-Bianco A, […], **Petrigna L**, […]. Combined effect of different factors on weight status and cardiometabolic risk in Italian adolescents. *Ital J Pediatr.* 2019;45(1):32.

-Hamilton LD, Mazzo MR, **Petrigna L**, Ahmed AA, Enoka RM. Poor estimates of motor variability are associated with longer grooved pegboard times for middle-aged and older adults. *J Neurophysiol.* 2019;121(2):588-601.

-**Petrigna L**, et al. The evaluation of dual-task conditions on static postural control in the older adults: a systematic review and meta-analysis protocol. *Syst Rev.* 2019;8(1):188.

-**Petrigna L**, et al. A Review of Countermovement and Squat Jump Testing Methods in the Context of Public Health Examination in Adolescence: Reliability and Feasibility of Current Testing Procedures. *Front Physiol.* 2019;10:1384.

-Tabacchi G, […], **Petrigna L**, […]. Field-based tests for the assessment of physical fitness in children and adolescents practising sport: a systematic review within the ESA program. *Sustainability.* 2019; 11.

-**Petrigna L**, et al. Physical fitness assessment in Goalball: A scoping review of the literature. *Heliyon.* 2020;6(7):e04407.

-Thomas E, **Petrigna L**, […]. Percentile values of the standing broad jump in children and adolescents aged 6-18 years old. *Eur J Transl Myol.* 2020;30(2):9050.

-**Petrigna L**, et al. The execution of the Grooved Pegboard test in a Dual-Task situation: A pilot study. *Heliyon.* 2020;6(8):e04678.

-**Petrigna L**, et al. Dual-Task Conditions on Static Postural Control in Older Adults: A Systematic Review and Meta-Analysis. *J Aging Phys Act.* 2020:1-16.

-Petrucci M, **Petrigna L**, […]. Validation in Young Soccer Players of the Modified Version of the Harre Circuit Test: The Petrucci Ability Test. *Montenegrin Journal of Sports Science and Medicine*, 2021. 10 (1), Ahead of Print.

-Karsten B, **Petrigna L**, […]. Relationship Between the Critical Power Test and a 20-min Functional Threshold Power Test in Cycling. *Front Physiol*, 2020. 11: p. 613151.

-Tabacchi, G, **Petrigna L**, […]. An Interaction Path of Mothers' and Preschoolers' Food- and Physical Activity-Related Aspects in Disadvantaged Sicilian Urban Areas. *Int J Environ Res Public Health*, 2021. 18(6).

-Thomas, E, Bellafiore M, **Petrigna L**, […]. Peripheral Nerve Responses to Muscle Stretching: A Systematic Review. *Journal of Sports Science and Medicine*, 2021. 20: 258-267.

-**Petrigna, L**, et al. Time spent on the smartphone does not relate to manual dexterity in young adults. *BMC Neurosci*, 2021. **22**(1): 34