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A standard operating procedure for the physical performance analysis of wheelchair fencer: a scoping review

Physical fitness evaluation in wheelchair fencing

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ABSTRACT

BACKGROUND: Wheelchair fencing (WF) is a very practiced sport within the Paralympic world. A careful analysis of the characteristics and data of a WF athlete can be useful for coaches and movement experts to better plan a training program.

The objective of the study was to evaluate physical fitness evaluation methods adopted in wheelchair fencing and to propose a Standard Operating Procedures (SOP).

EVIDENCE SYNTHESIS: Original articles written in English were included in this review, and the population studied was composed of athletes who practice WF. Studies were searched from PubMed, Web of Science, and Scopus databases using keywords and Boolean operators. 8 studies were included in this review; most of the studies converge and agree on the physical, physiological, and technical characteristics of a WF athlete.

CONCLUSIONS: The scientific literature referring to this sport is very scarce, hence the need for new original studies to optimize the SOP proposed.

Keywords: disability; evaluation; performance; wheelchair sport; standard operating procedure (SOP).

1 INTRODUCTION

Constant physical activity, sports participation, and an active lifestyle represent, both in able-bodied and in people with disabilities, the primary conditions for contrasting/preventing pathologies and guaranteeing functional independence [1]. However, it has been demonstrated that people with disabilities practice less physical activity than able-bodied people [2, 3], a condition that can be attributed to factors such as physical, social, and financial barriers [4]. The most important sporting event for people with disabilities is represented by the Paralympic Games [5], created for the first time by Ludwig Guttmann, a German neurosurgeon in 1948 with the name "Stoke Mandeville Games" [6]. In its first representation, this competition was intended for Second World War veterans with spinal injuries or amputations [7]. Over the years, the Stoke Mandeville Games have been held in different cities and have seen the participation of athletes from all over the world. However, only in 1984 the International Olympic Committee (IOC) officially has approved the denomination of the Paralympic Games. These games, due to the increasingly widespread interest in the media, make it possible to show the world the abilities of people with disabilities [8], demonstrating feelings such as integration, equality, and equal opportunities [9, 10]. One of the oldest and most widely practiced disciplines at the Paralympic Games is wheelchair fencing (WF) [11]. WF is a sport practiced by people with physical disabilities and, as with any other Paralympic sport, there is an internal ranking to make the competitions fair and equitable [12, 13]. Athletes are divided into three levels of classification A, B, and C: category A includes athletes with the least disability (i.e., athletes with full trunk movement and good balance), B includes athletes who do not move their legs, have reduced trunk function and poor balance, while category C includes athletes with the highest level of disability (athletes with tetraplegia); category C does not form part of the Paralympic program. WF is a very energetic sport discipline that involves different muscles, mainly the muscles of the upper limbs and trunk, indeed in able-bodied fencing, the athlete can retreat to avoid the opponent's attack, while in Paralympic fencing due to the use of a wheelchair anchored to the platform it is necessary to optimize the reflexes and develop good trunk mobility [14]. As in fencing for able-bodied, there are also three different disciplines in Paralympic fencing based on the weapon used: epee, foil, and saber. Consequently, an athlete with a disability can choose the most congenial weapon. Usually, for each discipline, the matches are made up of an elimination round, and then one advance to the direct elimination match: every single match end with 15 points [14]. The rules, and technical elements (attacks, response, combinations of actions) of WF are very similar to those of conventional fencing [14].

Elite fencers are constantly evaluated through tests, a search only on PubMed adopting the string "fence and physical evaluation" find 88 articles on this topic, while the same string with the word wheelchair fence detect only 2 articles. This highlights the necessity of a further and deeper investigation for WF and their physical evaluation. Considering the complexity of the technical elements means that it is necessary to monitor, through the administration of test batteries, the level of athletes to reduce the risk of injury and optimize sports performance. It must be considered that the administration of field tests is simpler, faster, and less expensive than laboratory tests. The test battery to be used could be proposed as a standard operating procedure (SOP) [16]; a procedure already used for other Paralympic sports [17-19]. A SOP is a document that provides a battery of replicable tests to normalize the data [16]. For the above reasons, this review aims to examine the scientific literature, to propose a SOP, containing field tests, to be used for the evaluation of athletes practicing WF.

2 MATERIALS AND METHODS

This review followed the principles of the preferred reporting for systematic reviews and meta-analyses for Scoping Reviews (PRISMA-ScR) checklist and explanation [20]. The manuscript was not previously recorded.

2.1 ELIGIBILITY CRITERIA

According to PRISMA guidelines, inclusion and exclusion criteria for participants, intervention, comparison, outcomes, and study design (PICOs) were adopted. Participants included in the study were elite athletes with international experience. No eligibility criteria were adopted regarding the type of intervention, the manuscripts were included if WF athletes were considered in the study. Related to comparison and outcomes, all evaluation typologies related to physical performance were included. For study design, observational, randomized, clinical, and longitudinal studies were included. Reviews, meta-analyses, opinions, abstracts, letters, and editorials were not taken into consideration.

2.2 DATA COLLECTION PROCESS

Studies were searched from PubMed (NLM), Web of Science (TS), and Scopus databases. Two keyword groups were created and matched using the Boolean operator AND and OR. The keyword terms were:

Keywords 1: wheelchair fencing, wheelchair fencer.

Keywords 2: physical fitness, sports physiology, performance analysis.

An example of matching was wheelchair fencing AND (physical fitness OR performance analysis).

2.3 RECORD, MANAGEMENT, AND ANALYSIS OF THE MANUSCRIPT

The studies detected on the electronic databases were screened to identify any duplicates and eliminate manuscripts that did not comply with the inclusion/exclusion criteria.

In the first phase of the analysis, the screening was performed by title, then on the abstract, and finally the complete text was analyzed. In each phase, two investigators performed the screening independently, and if there were doubts about the inclusion or exclusion of an article, the principal investigator was involved.

When the screening process was finished, a spreadsheet was created in Microsoft Excel® (Microsoft Corp., Redmond, WA) to enter the data relating to the individual manuscripts: first author and year of publication, sample size, age and gender of the sample, and motor skills evaluated.

3 EVIDENCE SYNTHESIS

After the manuscript search, a total of 92 manuscripts were found, 60 were excluded because they were duplicates. After the screening against the inclusion and exclusion criteria, 19 articles were excluded because they analyzed other topics and 5 for other reasons. At the end of the analysis, 8 manuscripts were included. The PRISMA flowchart depicts the entire selection process (figure 1).

* Figure 1 about here *

3.1 PARTICIPANTS CHARACTERISTICS

A total of 117 athletes were involved in the analysis and of them 32 were males and 16 were females; 69 were not specified (4 studies had not reported the gender of their participants). The analyzed sample presented a very wide distribution: elite athletes (64%), national athletes (27%), and able-bodied athletes who perform WF. More information is provided in Table 1.

Table 1, General information related to the included studies

1^ author, year	***Objective***	***Number [WF] [m] [f]***	***Level of subjects***
Bernardi, 2003[21]	Evaluate the cardiovascular benefits induced by sports practiced by athletes with different motor disabilities.	117 [30] [Na] [Na]	E
Bernardi, 2010[22]	Describe the cardiorespiratory response of Paralympic athletes during a simulated competition and evaluate the relationship between field performance and aerobic capacity.	34 [6] [6] [0]	E
Błaszczyszyn [23], 2021	Evaluate the synchronization of the trunk stabilizing muscles of wheelchair fencers	16 [16] [8] [8]	E
Borysiuk, 2022[24]	Evaluate the correct movement patterns of fencing techniques in wheelchair fencers	16 [16] [Na] [Na]	E
Borysiuk, 2022[25]	Evaluate muscle co-activation and muscle activity time in wheelchair fencing	16 [16] [Na] [Na]	NT
Borysiuk, 2020[26]	Determine the structure of the movement pattern performed during a wheelchair lunge, performed in response to visual and sensory input	7 [7] [Na] [Na]	E

Borysiuk, 2020[27]	Evaluate movement patterns among women and men in wheelchair fencing with a focus on postural muscles	16 [16] [8] [8]	NT
Iglesias, 2019[28]	Determine the cardiorespiratory demands of fencing and wheelchair fencing	10 [10] [10] [0]	AS

Legend: E = Elite, WFC = Conventional fencing, SB = Sedentary disabled, NT= National team, AS= Able-bodied subjects, Na= Not available

3.2 STUDIES CHARACTERISTICS

There are few studies, present in the scientific literature, that use field tests to evaluate WF athletes; in detail, there are two physical performance parameters taken into consideration by the authors, among these it was detected in 3 studies the maximum rate of oxygen consumption (VO2peak) and in 5 studies the muscle activation. More details can be seen in Table 2. Cardiorespiratory fitness has been evaluated in a few articles, in particular, the researchers in these studies used a portable metabolite and a heart rate monitor (placed on the chest) during a race simulation, noting that the physiological demands of WF are lower than those of standing fencing, the researchers also demonstrated that the sport with the greatest adaptation in terms of VO2peak is Nordic skiing, while intermediate values were found for wheelchair fencing [21]. In addition, Bernardi and colleagues discovered that the sports performance of a wheelchair Paralympic athlete depends on his cardiorespiratory capacity [22].

A total of 5 studies analyzed muscle activation; in detail, all the researchers used an electromyographic examination and an accelerometer with the evaluation carried out during the execution of an attack by the fencer. The tests were preceded by an individual warm-up phase and provided for the standardization of the competition platform (the fencing platform with the fencers' wheelchairs was set up so that the end of the weapon was in contact with the bent arm of the trainer).

The results showed clear trunk muscle activity in WF [23, 24, 27], and a lower muscle activation time for category A athletes compared to category B athletes [25]. The researchers also found a statistically significant difference in the initial phase of the technical attack movement between male and female athletes: female athletes initially activated the trunk extensor muscles, while male athletes initially activated the trunk flexor muscles [26]. This result would seem to testify that male and female athletes use different postural settings in the attack phase. The researchers also suggest the possibility of repeating the test batteries through different stimulations such as visual or sensory stimulation [27].

Table 2, Information related to physical fitness characteristics of the included studies

1^ author, year	***Reference parameters***
Bernardi, 2003 [21]	VO2peak
Bernardi, 2010[22]	VT - VO2peak
Błaszczyszyn, 2021 [23]	MA
Borysiuk, 2022 [24]	MA
Borysiuk, 2022 [25]	MA
Borysiuk, 2020 [26]	MA
Borysiuk, 2020 [27]	MA
Iglesias, 2019 [28]	VO2peak – EE - HR

Legend: VT= Ventilatory threshold, VO2peak= Peak oxygen uptake, EE= Energy expenditure, HR= Heart rate, MA= Muscle activation

4 DISCUSSION

The review highlights how little research has been conducted on WF, and how few field tests have been proposed to evaluate the sports performance and physical characteristics of an athlete who practices WF. Consequently, there is a need to create an SOP (Table 3) to standardize the physical fitness testing procedure for athletes of WF.

4.1 CARDIORESPIRATORY FEATURES

Cardiorespiratory capacity is an important parameter for analyzing the sporting performance of a WF athlete [22]. Consequently, in addition to evaluating VO2peak through the metabolite in a race simulation, it could be useful to insert an additional evaluation test. For this reason, within our SOP, it is possible to insert the Yo-Yo intermittent recovery adapted test [29]. The test measures the aerobic capacity of athletes, i.e. the parameter of maximum oxygen consumption. In detail, the greater the volume of maximum oxygen consumption, the greater the sports performance. The original test consisted of 20 m shuttle runs performed at increasing speed with 10 seconds of active recovery until exhaustion [30]. The test already has an adapted protocol for wheelchair athletes, as it is already used for other wheelchair sports [31]. The protocol, due to the differences between running and pushing the wheelchair, consists of 10 m of wheelchair running with progressively increasing speed, alternating with 10 seconds of active recovery [32]; the test ends when the athlete is unable to cover a shuttle at the expected speed. For the evaluation, the total distance covered by the athlete is measured. This test is proposed in our SOP because it is a quick and simple method to collect data on an athlete's ability to perform intense and repeated exercises. Considering that wheelchair fencing has several technical elements within it that require intense, repeated, and long-lasting actions.

4.2 MUSCLE STRENGTH AND ENDURANCE

None of the studies analyzed has the objective of evaluating the muscle strength of an athlete who practices WF, although muscle strength is a widely used parameter for other wheelchair sports [33, 34]. One of the main tests adopted for the evaluation of strength in wheelchair athletes is the hand grip test [35-37]. In detail, the administration of this test allows the evaluation of the strength of the muscles of the forearm and hand, the assessment of primary importance in WF to manage and improve the athlete's grip with the weapon used. This test presents a specific protocol as recommended by the American Society of Hand Therapists [38]. The protocol provides for tightening a dynamometer as much as possible, carrying out the test in a sitting position with the back leaning against the backrest, the elbow at a 90° position, and the arm in a neutral position, not in touch with the trunk. Each athlete performs the test 3 times, both for the dominant and non-dominant limb. The indication by Ahmadi and colleagues for optimal data collection were to squeeze as hard as possible the instrument for 3 seconds [39].

4.3 FLEXIBILITY

Muscle flexibility in WF has not been evaluated in any study, although it is a relevant parameter in terms of injury prevention [40, 41]. One of the tests used in other wheelchair sports is the back scratch test, included in the Brockport Physical Fitness test manual [42]. The test measures how closely the hands can join behind the back. In detail, the protocol provides for a well-defined execution [43]: from a sitting position with the upper limbs placed behind the back with one hand over the shoulder and the other hand down the back. The distance (cm) between the second finger of one hand and the second finger of the other hand is measured (if the second finger of the left hand touches the second finger of the right hand the value is 0). The simplicity of administering the test makes it useful for testing the functional suitability of subjects in wheelchairs.

The use double-arm goniometer is another useful tool to be able to evaluate the range of motion of the elbow, wrist, or shoulder [44], however, its application requires specific tasks, so it is not recommended in our evaluation SOP.

4.4 ANTHROPOMETRIC VARIABLES

None of the studies analyzed considers the anthropometric measurements, however, for wheelchair athletes who practice other sports, one of the most used tests is the one related to the detection of skin folds [45]. This measurement is a common method for determining body fat composition. Although calipers require an accurate measurement technique for evaluation, this test is valid, inexpensive, accurate, and easy to perform in the field [46]. Skinfold measurement can use different anatomical sites around the body. In detail, the operator pinches the specific site to raise a layer of skin and the underlying adipose tissue. The calipers are then applied and a reading of the value in millimeters (mm) is taken two seconds later. The mean of two measurements should be taken. Wong and colleagues [47] decided to apply the skinfold test to wheelchair athletes through the administration of the two-point test, to make the test faster than the seven-point skinfold evaluation. For these reasons, we have decided to insert a 2-site skinfold thickness into the SOP.

STANDARD OPERATION PROCEDURE (SOP)

The SOP that could be used to evaluate WF athletes begins with the detection of skin folds at two points and follows with the execution of a 20-minute warm-up phase at low intensity. Subsequently, the battery of tests could be administered as follows: evaluation of the grip through the hand grip test, evaluation of flexibility through the back scratch test, cardiorespiratory evaluation through the Yo-Yo intermittent recovery adapted test or race simulation with portable metabolite, and conclusion the evaluation of muscle activation through a simulated race. Athletes must be instructed to perform each test to perform tests at the maximum intensity; it is also necessary to use an adequate recovery period between tests. Each athlete carries out every single test in his wheelchair.

Table 3, the standard operating procedure for evaluation of physical fitness of wheelchair fencing

Physical fitness component	***Test adopted***
Body composition	2-site skinfold thickness
Muscular strength	Handgrip test
Cardiorespiratory capacity	Yo-Yo intermittent recovery adapted test / Race simulation with portable metabolite
Muscle activation	Race simulation with electromyography
Flexibility	Back scratch test

Legend: Standard Operating Procedure for the evaluation of physical fitness of wheelchair fencing

The present study has limitations. An important limitation of the study is the scarcity number of included studies, but this condition highlights the importance of future original articles on this topic; a second limitation is related to the sample: the sample of athletes analyzed is small, not very detailed, made up of athletes with a different performance level and with different physical characteristics, not allowing a comparison of the results.

The proposed SOP is a first operational indication, it needs to be investigated and revised according to the publication of new original studies. Future studies should pay more attention to this topic, evaluating the fitness characteristics of WF using the proposed SOP, to create normative data, facilitating team evaluation. Future research should consider this topic more.

CONCLUSION

This SOP is useful for evaluating the physical characteristics of a WF athlete; it is also useful for coaches as it allows you to compare the results of your team and to develop a personalized training program at the level of the individual athlete.

References

1. Heath, G.W. and P.H. Fentem, *Physical activity among persons with disabilities--a public health perspective.* Exerc Sport Sci Rev, 1997. **25**: p. 195-234.
2. Jung, J., et al., *Meta-Analysis of Physical Activity Levels in Youth With and Without Disabilities.* Adapt Phys Activ Q, 2018. **35**(4): p. 381-402.
3. Diaz, R., et al., *Impact of Adaptive Sports Participation on Quality of Life.* Sports Med Arthrosc Rev, 2019. **27**(2): p. 73-82.
4. Blauwet, C.A. and L.I. Iezzoni, *From the Paralympics to public health: increasing physical activity through legislative and policy initiatives.* PM R, 2014. **6**(8 Suppl): p. S4-10.
5. Legg, D., *Paralympic Games: History and Legacy of a Global Movement.* Phys Med Rehabil Clin N Am, 2018. **29**(2): p. 417-425.
6. Silver, J.R., *Ludwig Guttmann (1899-1980), Stoke Mandeville Hospital and the Paralympic Games.* J Med Biogr, 2012. **20**(3): p. 101-5.
7. Matthews, D., M. Sukeik, and F. Haddad, *Return to sport following amputation.* J Sports Med Phys Fitness, 2014. **54**(4): p. 481-6.
8. Ferrara, K., J. Burns, and H. Mills, *Public attitudes toward people with intellectual disabilities after viewing Olympic or Paralympic performance.* Adapt Phys Activ Q, 2015. **32**(1): p. 19-33.
9. Blauwet, C. and S.E. Willick, *The Paralympic Movement: using sports to promote health, disability rights, and social integration for athletes with disabilities.* PM R, 2012. **4**(11): p. 851-6.
10. Gold, J.R. and M.M. Gold, *Access for all: the rise of the Paralympic Games.* J R Soc Promot Health, 2007. **127**(3): p. 133-41.

11. Caldwell, M. and A.J. De Luigi, *Wheelchair Fencing*, in *Adaptive Sports Medicine: A Clinical Guide*, A.J. De Luigi, Editor. 2018, Springer International Publishing: Cham. p. 181-189.
12. Tweedy, S.M., D. Mann, and Y.C. Vanlandewijck, *Research needs for the development of evidence-based systems of classification for physical, vision, and intellectual impairments*, in *Handbook of Sports Medicine and Science: Training and Coaching the Paralympic Athlete*. 2016. p. 122-149.
13. Tweedy, S.M. and Y.C. Vanlandewijck, *International Paralympic Committee position stand--background and scientific principles of classification in Paralympic sport.* Br J Sports Med, 2011. **45**(4): p. 259-69.
14. IWAS-Wheelchair-Fencing, *Rules for competition*. 2022.
15. *<1-IWF-Technical-Rules-October-2022.pdf>*.
16. Petrigna, L., et al., *The importance of standard operating procedures in physical fitness assessment: a brief review.* Sport Sciences for Health, 2022. **18**(1): p. 21-26.
17. Petrigna, L., et al., *How physical fitness is evaluated in sitting volleyball players? A scoping review.* J Sports Med Phys Fitness, 2022.
18. Petrigna, L., S. Pajaujiene, and G. Musumeci, *Physical fitness assessment in wheelchair basketball: A mini-review.* 2022. **4**.
19. Petrigna, L., et al., *Physical fitness assessment in Goalball: A scoping review of the literature.* Heliyon, 2020. **6**(7): p. e04407.
20. Tricco, A.C., et al., *PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation.* Ann Intern Med, 2018. **169**(7): p. 467-473.
21. Bernardi, M., et al., *Are sports practiced by athletes with locomotor disabilities effective in determining health benefits?* Medicina dello Sport, 2003. **56**(4): p. 277-286.

22. Bernardi, M., et al., *Field evaluation of paralympic athletes in selected sports: Implications for training.* Medicine and Science in Sports and Exercise, 2010. **42**(6): p. 1200-1208.
23. Błaszczyszyn, M., et al., *Wavelet coherence as a measure of trunk stabilizer muscle activation in wheelchair fencers.* BMC Sports Sci Med Rehabil, 2021. **13**(1): p. 140.
24. Borysiuk, Z., et al., *Electromyography, Wavelet Analysis and Muscle Co-Activation as Comprehensive Tools of Movement Pattern Assessment for Injury Prevention in Wheelchair Fencing.* Applied Sciences (Switzerland), 2022. **12**(5).
25. Borysiuk, Z., et al., *Movement Patterns of Polish National Paralympic Team Wheelchair Fencers with Regard to Muscle Activity and Co-Activation Time.* Journal of Human Kinetics, 2022. **82**(1): p. 223-232.
26. Borysiuk, Z., et al., *Movement patterns and sensorimotor responses: Comparison of men and women in wheelchair fencing based on the polish paralympic team.* Archives of Budo, 2020. **16**: p. 19-26.
27. Borysiuk, Z., et al., *Neuromuscular, Perceptual, and Temporal Determinants of Movement Patterns in Wheelchair Fencing: Preliminary Study.* BioMed Research International, 2020. **2020**.
28. Iglesias, X., et al., *Physiological demands of standing and wheelchair fencing in able-bodied fencers.* J Sports Med Phys Fitness, 2019. **59**(4): p. 569-574.
29. Bangsbo, J., F.M. Iaia, and P. Krustrup, *The Yo-Yo intermittent recovery test : a useful tool for evaluation of physical performance in intermittent sports.* Sports Med, 2008. **38**(1): p. 37-51.
30. Krustrup, P., et al., *The Yo-Yo Intermittent Recovery Test: Physiological Response, Reliability, and Validity.* Medicine & Science in Sports & Exercise, 2003. **35**(4).

31. Castagna, C., et al., *The Yo-Yo intermittent recovery test in basketball players.* J Sci Med Sport, 2008. **11**(2): p. 202-8.

32. Yanci, J., et al., *Sprint, agility, strength and endurance capacity in wheelchair basketball players.* Biol Sport, 2015. **32**(1): p. 71-8.

33. Shephard, R.J., *Sports medicine and the wheelchair athlete.* Sports Med, 1988. **5**(4): p. 226-47.

34. Mason, B.S., et al., *Optimising classification of proximal arm strength impairment in wheelchair rugby: A proof of concept study.* J Sports Sci, 2021. **39**(sup1): p. 132-139.

35. Gil, S.M., et al., *The Functional Classification and Field Test Performance in Wheelchair Basketball Players.* J Hum Kinet, 2015. **46**: p. 219-30.

36. Iturricastillo, A., C. Granados, and J. Yanci, *Changes in Body Composition and Physical Performance in Wheelchair Basketball Players During a Competitive Season.* J Hum Kinet, 2015. **48**: p. 157-65.

37. Kopiczko, A. and J. Cieplinska, *Forearm bone mineral density in adult men after spinal cord injuries: impact of physical activity level, smoking status, body composition, and muscle strength.* BMC Musculoskelet Disord, 2022. **23**(1): p. 81.

38. Spijkerman, D.C., et al., *Standardization of grip strength measurements. Effects on repeatability and peak force.* Scand J Rehabil Med, 1991. **23**(4): p. 203-6.

39. Ahmadi, S., M.C. Uchida, and G. Gutierrez, *Physical Performance Tests in Male and Female Sitting Volleyball Players: Pilot Study of Brazilian National Team.* Asian Journal of Sports Medicine, 2019. **10**: p. e85984.

40. Ingraham, S.J., *The role of flexibility in injury prevention and athletic performance: have we stretched the truth?* Minn Med, 2003. **86**(5): p. 58-61.

41. Gleim, G.W. and M.P. McHugh, *Flexibility and its effects on sports injury and performance.* Sports Med, 1997. **24**(5): p. 289-99.

42. Winnick, J.P. and F.X. Short, *The Brockport physical fitness test manual*. 1999: Human Kinetics.

43. Dewhurst, S., T.M.J.A.j.o.p.m. Bampouras, and rehabilitation, *Intraday reliability and sensitivity of four functional ability tests in older women.* 2014. **93**(8): p. 703-707.

44. Wang, Y.T., et al., *Contributions of selected fundamental factors to wheelchair basketball performance.* Medicine and Science in Sports and Exercise, 2005. **37**(1): p. 130-137.

45. Jackson, A.S. and M.L. Pollock, *Generalized equations for predicting body density of men.* Br J Nutr, 1978. **40**(3): p. 497-504.

46. Lamb, K.L., D.A. Brodie, and K. Roberts, *Physical fitness and health-related fitness as indicators of a positive health state.* Health Promotion International, 1988. **3**(2): p. 171-182.

47. Wong, M.Y.C. and K.M.J.A.J.o.S.M. Leung, *Effects of Sitting Light Volleyball Intervention on Physical Fitness Among Hong Kong Students with Physical Disabilities: A Pilot Quasi-Experimental Study.* 2020.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript

Authors' contributions.— Ignazio Leale, Giuseppe Battaglia, Luca Petrigna, Giuseppe Musumeci, and Antonio Palma contributed to the study's conception and design. The literature search has been performed by Ignazio Leale and Luca Petrigna. Data analysis has been performed by Ignazio Leale, Luca Petrigna, Valerio Giustino, and Ricardo Augusto Barbieri. The first draft of the manuscript was written by Ignazio Leale, Luca Petrigna, and Valerio Giustino. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

TITLES OF FIGURES

Figure 1.– Flow Diagram representing the selection process of manuscripts.