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Title

Physical performance measures of flexibility, hip strength, lower limb power and trunk endurance in healthy Navy cadets: normative data and differences between sex and limb dominance.

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Abstract:

The objectives were to provide normative data on commonly used physical performance tests that may be associated with musculoskeletal injuries in Navy cadets, and assess for sex and limb dominance differences. A large cohort of Navy cadets were assessed for physical performance tests of flexibility (ankle dorsiflexion range of motion and sit and reach), isometric hip strength, lower limb power (single leg hop), and trunk endurance (plank and side plank tests). Besides providing normative data tables, sex and limb dominance differences were assessed by a two-way mixed ANOVA. A total of 545 Brazilian Navy cadets (394 males) representing 79% of the cadets in the Academy participated. Normative reference values were reported as mean±SD, 95%CI and percentiles. For tests of muscle strength, power and endurance, males performed better than females ($p<0.001$). For flexibility tests, females achieved greater distances than males for the sit and reach test ($p<0.001$), but no difference for ankle dorsiflexion ($p=0.51$). Overall, there were no clinically relevant differences between limbs. In conclusion, normative data for commonly used physical performance tests were provided. Although no clinically relevant side-to-side differences were found, males presented higher values for lower limb strength and power, as well as trunk endurance than females, while females demonstrated increased flexibility. Valuable normative data are provided to professionals who work with young, active populations from the injury prevention or rehabilitation perspective; as the current study may help professionals to identify athletes or cadets whose performance is outside the normative values and may be at risk for injury.

Keywords: reference values; norms; sex characteristics; Lower Extremity

Physical performance measures of flexibility, hip strength, lower limb power and trunk endurance in healthy Navy cadets: normative reference values and differences between sex and limb dominance.

INTRODUCTION

Musculoskeletal diseases and injuries are a considerable burden worldwide, affecting young, healthy and physically active population such as college students(1), those participating in high level sports(9) and military personnel(6). Therefore, in order to develop effective preventive strategies, many studies have focused on identifying risk factors for musculoskeletal injury(14, 15, 26).

For example, isometric hip muscle strength has been shown to independently predict future non-contact ACL injury in athletes(14), while low levels of physical fitness(26) and lower limb power(15) have been suggested as potential risk factors of overuse injuries in the military. However, the costly nature of sophisticated research equipment is a barrier for many institutions and professionals, so different cost effective clinical tests to measure hip muscle strength, trunk endurance, lower limb power have been proposed in order to assess participant's performance and injury risk(4, 14, 23).

An important step in the identification of risk factors for musculoskeletal injuries is the establishment of extensive and reliable reference benchmarks for clinically relevant tests. Nevertheless, in the military, although physical performance tests are widely used to assess incoming cadets, there is a lack of normative reference values for this population. Furthermore, previous reference values presented some limitations; such as, non-normalized data(7, 19, 27), variability in participant's age(19) while few studies assessed differences between sex(3) and leg dominance(29).

Thus, the primary purpose of this study was to provide normative reference values on common physical performance tests of flexibility, hip strength, lower limb power and trunk endurance in Navy cadets. The secondary purpose was to assess for sex and limb dominance differences.

METHODS

Experimental Approach to the Problem

This was a cross-sectional study with data collected between January and March of 2016 at the beginning of cadet's academic year. Nine physiotherapists or sports science professionals experienced in daily physical and functional assessments in the military, participated as testers. In order to ensure consistency, test administrators were located at the same station during the duration of the study. All participants rotated around the five stations: (1) anthropometric, (2) flexibility, (3) hip isometric strength, (4) single leg hop and (5) plank/side plank tests, in the same sequence with a cluster randomization in regard to which limb (dominant/non-dominant) would start the test on that specific day.

Subjects

There were 688 Navy cadets (516 males and 172 females) as potential participants from a Brazilian Merchant Navy Academy. Inclusion criteria were age older than 18 years old, no current lower extremity or trunk pain, no surgery in the lower extremities in the last 12 months, and no medical or neuromusculoskeletal disorders that limit participation in the study. From 688 cadets, three were excluded due to current injury, 10 declined to participate and 130 did not show up for the assessment. A total of 545 Navy cadets volunteered (394 males and 151 females), corresponding to 79% of the Merchant Navy Academy population. For both sexes age ranged from 18 to 25 years old, the mean height and weight for males were 1.75 (SD 0.07) m and 75.5 (SD 12) kg, while for females 1.62 (SD 0.05) m and 61.2 (SD 8.2) kg. This study was approved by the Marcilio Dias Naval Hospital's ethical committee and all subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent form to participate in the study.

Procedures

After an extensive review of the literature, extensive discussions within the research team and close consultation with our Navy partners the following tests were chosen based on simplicity to perform and potential links to injury risk and implementation as a standard baseline assessment in the military. All tests were performed inside a gymnasium with temperature controlled by air conditioning and participants were instructed to avoid any strenuous activity before the evaluation.

Flexibility tests

The weight-bearing lunge test and a digital inclinometer (Baseline, Fabrication Enterprises Inc, White Plains, NY) were used to assess ankle dorsiflexion range of motion (ROM) bilaterally (Supplemental digital content 4, http://links.lww.com/JSCR/A72). A vertical line (piece of tape) was attached on the wall extending to the floor and participants were requested to place their big toe and heel aligned along the line while they were barefoot. Then, they were asked to lunge forward, in an upright position, moving their knee toward the vertical line while keeping the entire heel on the floor. Once they reached maximal ankle dorsiflexion angle without lifting up the heel, a digital inclinometer was placed on the Achilles tendon's midpoint and the angle was measured(18). Three measurements were collected and averaged.

For the sit and reach test, participants assumed the long sitting position barefoot and placed their soles against the sit and reach test box at the 26 cm mark. Then, they were asked to place one hand on top of the other and slowly flex their trunk forward trying to reach the most distant point with their fingertips while keeping their knee extended (Supplemental digital content 4, http://links.lww.com/JSCR/A72). Three measurements were recorded and the best two were averaged and used for the analysis. Previous studies have reported a very high intra and inter-rater reliability for the weight-bearing lunge test(16) and the sit and reach test(20).

Maximal hip isometric strength

The maximal voluntary isometric contraction of the hip abductor and external rotator muscles were evaluated using a calibrated hand-held dynamometer (Lafayette Manual Muscle Tester Model 01163; Lafayette Instrument Company, Lafayette, IN, USA), Figure 1. For both tests, after a practice trial at submaximal effort, participants were instructed to perform three maximal voluntary isometric contractions of five seconds each, followed by five seconds rest in between each repetition(28). A standardized verbal encouragement ‘‘go-go–go-go’’ was used by the tester. The hand-held dynamometer was placed 5 cm above of the proximal edge of the lateral and medial malleolus when testing the hip abductors and external rotators, respectively(28). For both tests, three measurements were collected and the average was normalized to body weight. Previous studies have reported that a handheld dynamometer has good to excellent test-retest reliability for maximal hip isometric strength(12).

<<Insert Figure 1>>

Single-leg hop test for distance

For the single leg hop test, a horizontal adhesive tape (start line) was attached to the floor and a tape measure was fixed perpendicular to it. Prior to the test, participants were required to stand directly behind the start line and after a brief explanation, one practice trial at submaximal effort was allowed for each leg. Participants performed six single leg hop (alternating legs) trying to reach the longest distance(5) (Supplemental digital content 5, http://links.lww.com/JSCR/A73). As the purpose of this test was to measure the lower extremity power and not knee biomechanics during landing, participants were instructed to push off with one leg but to land with both, thus decreasing the risk of a possible injury.

The distance was measured from the starting line to the rearmost leg's heel(5). In order to mimic sports activities, no restrictions were applied to arm movements; and if a participant was unable to land correctly, for instance, lost balance or took an extra step, that trial was repeated. The mean of the three trials of each leg was normalized to the participant's height and used for further statistical analysis(5). The single leg hop test is a reliable method to assess the single-leg horizontal distance competence(22).

Plank and Side plank tests

Trunk endurance was estimated by using the plank and side plank tests (Figure 2). Participants had to begin the plank test in the standard prone bridge position supported by the forearms and feet in contact with the ground. Elbows were placed at 90° of flexion underneath the shoulders, while the neck and hip were maintained in neutral position(30). In order to standardize the assessment, an adaptation of the method described by Tong et al(30) was used. An elastic string was attached horizontally to a pair of vertical pipes, and prior to the assessment, the tester positioned the participant in the start position and placed the string adjacent to the participant's Gluteus Maximus muscle which worked as a physical reference for an objective measurement.

For the Side plank test, most procedures were similar to the plank test; however, the side plank was performed on both sides. Prior to beginning, the tester instructed the participants to assume the side plank position with legs extended and the elbow from the lower side flexed 90° and positioned underneath the shoulder (10). For this test, two pipes were used to fix the strings which were placed adjacent to the participant's higher hip. The tester instructed the participants to lift their hips up and maintain a straight body position while keeping the top arm flexed at the elbow. Then, the string was placed touching the participant's higher hip

Both tests were ended if the participant's pelvis dropped below the string (reference line) after two consecutive warnings; the participant did not hold the correct posture up to the end; dropped down to the floor; or after maintaining the position for the required 60 seconds (60s)(30). Previous studies have demonstrated that the plank test and side plank test are a valid and reliable method to assess trunk muscle endurance(20, 30).

<<Insert Figure 2>>

Statistical Analyses

IBM SPSS Statistics 22.0 for Windows (IBM Corporation, Armonk, New York) was used for the statistical analysis and the level of significance was set, a priori, at $\alpha = 0.05$. Normality was tested using Q-Q Plots, while outliers were tested by inspecting a boxplot for values greater than 1.5 box-lengths from the edge of the box.

Normative reference values were presented as means and standard deviations with 95% confidence Intervals, and percentiles were reported for each test. A two-way mixed ANOVA was used to test for the main effects of sex and leg dominance, and their interaction with the dependent variables (ankle dorsiflexion, maximal hip isometric strength and single-leg hop test).

Regarding the sit and reach test, as data were normally distributed, an independent T- test was used to determine if a difference existed between sexes. Nevertheless, for the plank test and side plank test, as data were not normally distributed, the nonparametric Mann-Whitney U test was performed to determine if there were differences between sexes and the Wilcoxon signed-rank test was used for the side plank test to determine, whether there were differences between sides within each sex. Specifically for the side plank test analysis, in order to avoid problems with multiple comparisons, the Bonferroni correction was used and the α value was adjusted to 0.025 (0.05/2 comparisons).

RESULTS

Flexibility tests

There was no interaction between leg dominance and sex ($p = 0.71$) or main effect for sex ($p = 0.51$) for ankle dorsiflexion ROM. However, there was a main effect of leg dominance ($p = 0.01$) where the non-dominant leg presented greater ROM than the dominant. Regarding the sit and reach test, females presented higher distances than males ($p<0.001$), table 1.

<<Insert Table 1>>

Maximal hip isometric strength

There was an interaction effect between sex and leg dominance on maximal hip external rotation isometric strength ($p < 0.001$). After a post-hoc analysis, the dominant leg showed increased hip external rotation strength than the non-dominant in males ($p < 0.001$), but not in females ($p=0.92$). Additionally, males demonstrated higher maximal hip external rotation isometric strength than female for both the dominant and non-dominant legs ($p < 0.001$).

There was no interaction effect between sex and leg dominance on hip abduction strength ($p = 0.64$) and no main effect of leg dominance ($p=0.07$); however, there was a main sex effect with males presenting higher values than females ($p < 0.001$), table 1 and Supplemental digital content 1 (http://links.lww.com/JSCR/A74).

Single-leg hop test for distance

There was no interaction effect between leg dominance and sex on single leg hop test for distance normalized to height ($p = 0.61$). However, there was a main effect for sex ($p < 0.001$) with males jumping farther than females, while there was no effect for leg dominance ($p=0.21$).

Plank and Side plank tests

For the plank test, males performed better than females ($p<0.001$). Moreover, 85% of males and 60% of females held the position for the maximum 60s. Similarly, for the side plank test males performed better than females ($p<0.001$), but no difference was found between body sides.

DISCUSSION

In this large study of healthy Navy cadets, a number of important findings emerged: a) normative reference values for physical performance tests in a young, active, injury-free population were provided; b) males demonstrated greater normalized maximal hip isometric strength and lower limb power, as well as trunk endurance than females, while females had higher flexibility in the sit and reach test, c) there were largely no side-to-side differences.

Although, most of the time direct comparisons with previous studies were limited by different sample sizes, participant's characteristics and different methodology (e.g. non-normalized data); prior studies(3) (25) reported similar findings of maximal hip isometric abduction torque and hip external rotators strength. For the single leg hop test, previous studies(7, 19) did not normalize their data by the participant's height, not allowing for direct comparisons; nevertheless, Brumitt et al(4) evaluated Division III collegiate athletes and normalized their results per athlete's height and reported lower values than ours which may be due to the difference in protocols (males jumped – 75% and females – 66% of their height).

In terms of sex differences, our findings are consistent with previous studies, as males demonstrated higher values than females for muscle strength, power and endurance, while the opposite was true for flexibility (sit and reach test). Prior studies have reported similar results related to sex differences for each of these tests; for instance, maximal hip isometric strength(3), single leg hop test(7, 19), trunk endurance(24), as well as sit and reach test(17). It has been suggested and consistently reported that these strength differences may be explained due to larger muscle cross-sectional area(13) and higher testosterone levels(21) in males in comparison with females. On the other hand, there is evidence that hamstrings flexibility in females is higher in comparison with males(31), which may explain the increased values of the sit and reach test in the current study, as this test measures hamstring flexibility(31). Thus, these findings highlight the importance of reporting normative reference values separately for males and females to allow meaningful comparisons within sexes.

Generally, participants demonstrated consistent side-to-side symmetry with only two exceptions; ankle dorsiflexion ROM (difference on average of 0.3º in males and 0.4º in females) and male's maximal hip external rotation isometric strength (side to side difference on average of 7%).

Although these differences were statistically significant, they are not clinically relevant. Adding to that, it has been suggested that some level of limb asymmetry is expected(32); and, especially for hip muscle strength, previous studies have reported similar findings in uninjured people(29). The consistent side-to-side symmetry reported, endorse the utility of the current study as a valuable normative reference values, since previous studies suggested that large muscle imbalance is a common finding in injured people(11). Based on the current results, large asymmetries in muscle strength and flexibility appear to be uncommon, thus, the presence of large side-to-side differences may rise to the possibility of potential lower extremity injuries[35].

Finally, it has been suggested that even the non-injured limb can lose substantial amount of strength after a recovery period and to take it as a reference to evaluate the injured limb might be questionable(8). Thus, the normative reference values provided in the current study can be a useful tool to compare results, for uninjured, injured or injury-recovering population with similar population demographics.

This paper provides researchers, clinicians and strength and conditioning professionals with information on normative reference values for different physical performance measures in a young, active, injury-free homogeneous population (Table 2 and Supplemental digital content 1 to 3,

http://links.lww.com/JSCR/A74, http://links.lww.com/JSCR/A75,

http://links.lww.com/JSCR/A76). These normative reference values may allow for comparisons with physically active people, college athletes and cadets in the same age range. Likewise, as previously reported by Anderson et al.(2), providing the normative reference values in percentiles will allow participants in the same age range as in this study, to get a sense of how their performance in these commonly used tests ranks them among their peers.

The current study has some strengths, as it has been done in a large and homogenous sample. Moreover, due to different reported units, it is very difficult to compare maximal isometric strength data; so, to our knowledge this is the first study that presents maximal hip isometric strength results in different units of measurements (i.e. Kgf/BW, Lbs/BW, N/BW, and N.m/BW). Moreover, few normative reference values studies reported data for females as well as compared dominant and non-dominant legs. However, this study also has some limitations; participants were recruited through a convenience sampling method and, the cross-sectional design that does not allow inference regarding the cause and effect relationship. Finally, the plank test was limited to 60s so it may have produced a celling effect, as almost 85% and 60% of males and females, respectively, finished the test. Thus, from a practical point of view, it seems that for healthy young adults, the plank test should be tested for more than 60s.

In conclusion, this study provides normative reference values for commonly used physical performance tests in a young, active, injury-free population of Navy cadets; especially, between 18 to 25 years old. Regarding strength, power and endurance tests, males presented higher values than females. However, for the flexibility tests females reached higher distances than males in the sit and reach test while no sex differences were found for ankle dorsiflexion ROM. Taking into consideration leg or body side dominance, for most tests there were no clinically relevant side-to-side differences.

Practical Applications

The current study may help clinicians, researchers and strength and conditioning professionals to identify athletes or cadets whose performance may fall outside the normative reference values found in this study, which may put them at risk for injury.

The study provides normative reference values to health care professionals and scientists who work with young, active populations from the injury prevention perspective, but also to those who are recovering from an injury, as making comparisons between injured and non-injured legs in this situation would not be appropriate since both legs tend to lose muscle strength.

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REFERENCES

1. Agel J, Rockwood T, and Klossner D. Collegiate ACL Injury Rates Across 15 Sports: National Collegiate Athletic Association Injury Surveillance System Data Update (2004-2005 Through 2012-2013). Clin J Sport Med 26: 518-523, 2016.
2. Anderson AF, Irrgang JJ, Kocher MS, Mann BJ, and Harrast JJ. The International Knee Documentation Committee Subjective Knee Evaluation Form: normative data. Am J Sports Med 34: 128-135, 2006.
3. Bittencourt NF, Santos TR, Goncalves GG, Coelho AP, Gomes BG, Mendonca Lde M, and Fonseca ST. Reference values of hip abductor torque among youth athletes: Influence of age, sex and sports. Phys Ther Sport 21: 1-6, 2016.
4. Brumitt J, Heiderscheit BC, Manske RC, Niemuth PE, and Rauh MJ. Lower extremity functional tests and risk of injury in division iii collegiate athletes. International journal of sports physical therapy 8: 216-227, 2013.
5. Brumitt J, Heiderscheit BC, Manske RC, Niemuth PE, and Rauh MJ. Lower extremity functional tests and risk of injury in division iii collegiate athletes. Int J Sports Phys Ther 8: 216-227, 2013.
6. Cameron KL and Owens BD. The burden and management of sports-related musculoskeletal injuries and conditions within the US military. Clin Sports Med 33: 573-589, 2014.

7. De Carlo MS and Sell KE. Normative data for range of motion and single-leg hop in high school athletes. Journal of Sport Rehabilitation 6: 246-255, 1997.

8. Fitzgerald GK, Lephart SM, Hwang JH, and Wainner MRS. Hop tests as predictors of dynamic knee stability. Journal of Orthopaedic and Sports Physical Therapy 31: 588-597, 2001.

9. Grant ME, Steffen K, Glasgow P, Phillips N, Booth L, and Galligan M. The role of sports physiotherapy at the London 2012 Olympic Games. Br J Sports Med 48: 63-70, 2014.

10. Imai A and Kaneoka K. The relationship between trunk endurance plank tests and athletic performance tests in adolescent soccer players. Int J Sports Phys Ther 11: 718-724, 2016.

11. Ireland ML, Willson JD, Ballantyne BT, and Davis IM. Hip Strength in Females with and without Patellofemoral Pain. J Orthop Sports Phys Ther 33: 671-676, 2003.

12. Jackson SM, Cheng MS, Smith AR, Jr., and Kolber MJ. Intrarater reliability of hand held dynamometry in measuring lower extremity isometric strength using a portable stabilization device. Man Ther 27: 137–141, 2016.

13. Kanehisa H, Ikegawa S, and Fukunaga T. Comparison of muscle cross-sectional area and strength between untrained women and men. European journal of applied physiology and occupational physiology 68: 148-154, 1994.

14. Khayambashi K, Ghoddosi N, Straub RK, and Powers CM. Hip Muscle Strength Predicts Noncontact Anterior Cruciate Ligament Injury in Male and Female Athletes: A Prospective Study. Am J Sports Med 44: 355-361, 2016.

15. Kodesh E, Shargal E, Kislev-Cohen R, Funk S, Dorfman L, Samuelly G, Hoffman JR, and Sharvit N. Examination of the Effectiveness of Predictors for Musculoskeletal Injuries in Female Soldiers. J Sports Sci Med 14: 515-521, 2015.

16. Langarika-Rocafort A, Emparanza JI, Aramendi JF, Castellano J, and Calleja-Gonzalez J. Intra-rater reliability and agreement of various methods of measurement to assess

dorsiflexion in the Weight Bearing Dorsiflexion Lunge Test (WBLT) among female athletes. Physical therapy in sport : official journal of the Association of Chartered Physiotherapists in Sports Medicine 23: 37-44, 2016.

17. López-Miñarro PA, Andújar PSdB, and Rodríguez-García PL. A comparison of the sit-and-reach test and the back-saver sit-and-reach test in university students. Journal of Sports Science and Medicine 8: 116-122, 2009.

18. McKay MJ, Baldwin JN, Ferreira P, Simic M, Vanicek N, Hiller CE, Nightingale EJ, Moloney NA, Quinlan KG, Pourkazemi F, Sman AD, Nicholson LL, Mousavi SJ, Rose K, Raymond J, Mackey MG, Chard A, Hubscher M, Wegener C, Fong Yan A, Refshauge KM, and Burns J. 1000 Norms Project: protocol of a cross-sectional study cataloging human variation. Physiotherapy 102: 50-56, 2016.

19. Myers BA, Jenkins WL, Killian C, and Rundquist P. Normative data for hop tests in high school and collegiate basketball and soccer players. Int J Sports Phys Ther 9: 596-603, 2014.

20. Ozcan Kahraman B, Salik Sengul Y, Kahraman T, and Kalemci O. Developing a Reliable Core Stability Assessment Battery for Patients with Nonspecific Low Back Pain. Spine (Phila Pa 1976) 41: E844-850, 2016.

21. Ramos E, Frontera WR, Llopart A, and Feliciano D. Muscle strength and hormonal levels in adolescents: gender related differences. Int J Sports Med 19: 526-531, 1998.

22. Ross MD, Langford B, and Whelan PJ. Test-retest reliability of 4 single-leg horizontal hop tests. J Strength Cond Res 16: 617-622, 2002.

23. Strand SL, Hjelm J, Shoepe TC, and Fajardo MA. Norms for an Isometric Muscle Endurance Test. J Hum Kinet 40: 93-102, 2014.

24. Strand SL, Hjelm J, Shoepe TC, and Fajardo MA. Norms for an Isometric Muscle Endurance Test. Journal of human kinetics 40: 93-102, 2014.

25. Suzuki H, Omori G, Uematsu D, Nishino K, and Endo N. The influence of hip strength on knee kinematics during a single-legged medial drop landing among competitive collegiate basketball players. International journal of sports physical therapy 10: 592, 2015.

26. Taanila H, Suni JH, Kannus P, Pihlajamaki H, Ruohola JP, Viskari J, and Parkkari J. Risk factors of acute and overuse musculoskeletal injuries among young conscripts: a population-based cohort study. BMC Musculoskelet Disord 16: 104, 2015.

27. Teyhen DS, Riebel MA, McArthur DR, Savini M, Jones MJ, Goffar SL, Kiesel KB, and Plisky PJ. Normative data and the influence of age and gender on power, balance, flexibility, and functional movement in healthy service members. Mil Med 179: 413, 2014.

28. Thorborg K, Petersen J, Magnusson SP, and Hölmich P. Clinical assessment of hip strength using a hand-held dynamometer is reliable. Scand J Med Sci Sports 20: 493-501, 2010.

29. Thorborg K, Serner A, Petersen J, Moller Madsen T, Magnusson P, and Hölmich P. Hip Adduction and Abduction Strength Profiles in Elite Soccer Players: Implications for Clinical Evaluation of Hip Adductor Muscle Recovery After Injury. The American Journal of Sports Medicine 39: 121-126, 2011.

30. Tong TK, Wu S, and Nie JL. Sport-specific endurance plank test for evaluation of global core muscle function. Phys Ther Sport 15: 58-63, 2014.

31. Youdas JW, Krause DA, Hollman JH, Harmsen WS, and Laskowski E. The influence of gender and age on hamstring muscle length in healthy adults. J Orthop Sports Phys Ther 35: 246-252, 2005.

32. Zifchock RA, Davis I, Higginson J, McCaw S, and Royer T. Side-to-side differences in overuse running injury susceptibility: a retrospective study. Hum Mov Sci 27: 888-902, 2008.

Figure Legends

Figure 1. Hip Abduction (A-B) and External Rotation (C-D) assessment.ppt

Figure 2. Plank (E-F) and side plank tests (G-H).ppt

Table 1. Normative physical performance measures (Mean±SD and 95%CI)

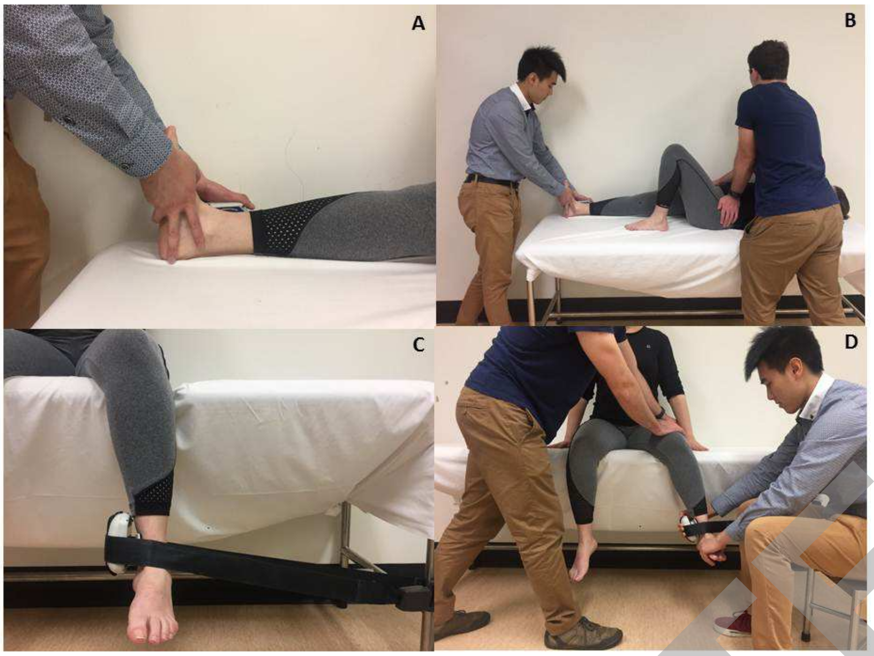
		Male (n=394)				Female (n=151)			
Ankle dorsiflexion (°)	DS	32.7	±	6.6€	(32-33.3)	32.2	±	7.1€	(31-33.3)
	NDS	33.0	±	6.9€	(32.3-33.7)	32.6	±	7.0€	(31.4-33.7)
Sit and Reach (cm)		24.4	±	8.2*	(23.6-25.2)	28.8	±	8.2*	(27.5-30.1)
Hip Abduction (kg/BW)¥	DS	0.18	±	0.04*	(0.18-0.19)	0.16	±	0.04*	(0.15-0.17)
	NDS	0.18	±	0.04*	(0.18-0.19)	0.16	±	0.04*	(0.16-0.17)
*Hip External Rotation (kg/BW)*Ω	DS	0.28	±	0.07€*	(0.27-0.29)	0.19	±	0.05*	(0.18-0.20)
	NDS	0.26	±	0.06€*	(0.25-0.26)	0.19	±	0.05*	(0.18-0.19)
Single Leg Hop (%height)	DS	85.5	±	11.9*	(84.3-86.6)	69.4	±	9.9*	(67.8-71)
	NDS	85.3	±	12.4*	(84.0-86.5)	68.9	±	10.6*	(67.2-70.6)
Plank Test (s)		57.5	±	7.6*	(56.7-58.2)	52.8	±	11.4*	(51-54.7)
Side Plank Test (s)#	DS	50.8	±	13.4*	(49.5-52.1)	39.2	±	18.5*	(36.1-42.1)
	NDS	50.3	±	13.6*	(49-51.7)	36.2	±	16.8*	(33.4-38.9)

DS - Dominant side, NDS - Non-dominant side and BW - body weight in kilograms, s - second

#males (n=393) and females (n=150) due to missing data

€Significant leg ($p \leq 0.05$) and *sex differences ($p<0.001$)

¥males (n=392) and Ωfemales (n=150) due to some outliers.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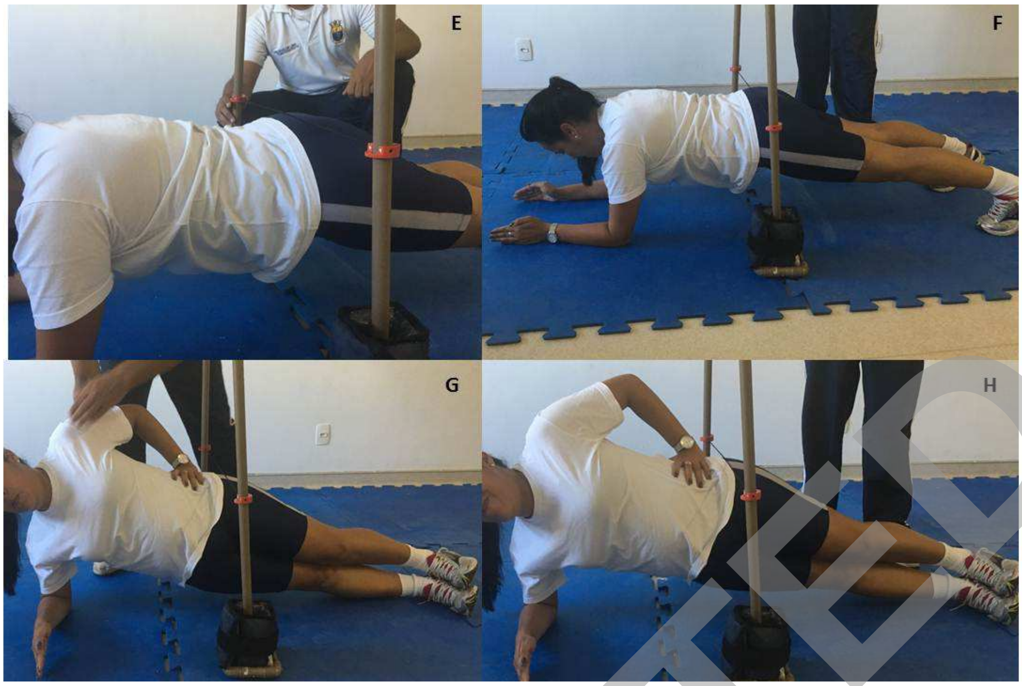
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