BIOMECHANICAL AND PHYSICAL PROFILE COMPARISON IN MILITARIES WITH AND WITHOUT MUSCULOSKELETAL INJURIES: A PRELIMINARY STUDY

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This study compared limb strength, body composition, cardiorespiratory fitness and vertical jump performance in military staff with and without prior musculoskeletal injures. Thirty male military personnel enrolled in a physical education undergraduate program participated in this study. A survey covering history of the last two years of musculoskeletal lower limb injuries was sent to participants, who were separated into groups: injured (IG; n=16) and uninjured (NIG; n=14). Participants performed a sit and reach flexibility test, body composition, 12-min Cooper running test, vertical jump performance and back squat in a smith machine on five different days. Participants from the IG presented reduced strength and vertical jump performance compared to the NIG. No differences were observed in body composition, or cardiorespiratory fitness between groups.

KEYWORDS: Vertical jump, strength, injure prevention.

INTRODUCTION: Although the benefits of sports participation are well known, physical activity may also cause sports injuries in elite and recreational athletes which might lead to sports discontinuation. The lower extremities are affected in 47–54% of all sports injuries (Cassel et al., 2019). Acute injuries usually result in short term disabilities; whereas overuse injuries may result in chronic, long-lasting limitations and are three- to six-fold more frequent (Cassel et al., 2019). Military personnel often engage in strenuous physical activity, which result, in cumulative injuries to range from 25% to 37% (Knapik et al., 2015). These injuries often affect the lower limbs, with cases of stress fractures of the tibia and metatarsals, and retropatellar pain syndrome being reported. Previous injury is associated with an increase in the risk of subsequent injury that may be associated with incomplete neuromuscular rehabilitation (Fulton et al., 2014). Therefore, assessing how military staff recover from injuries is important to anticipate the risk of following injuries. The objective of this study was to compare strength, vertical jump performance, body composition and cardiorespiratory fitness in the lower limbs of military staff with and without a history of musculoskeletal injury.

METHODS: Thirty male first-year military students at the Physical Education School of Brazilian Army took part in this preliminary retrospective study. All the participants were physically active and were involved in structured military physical training regime (moderate and vigorous activities for at least 3 times a week, each one with 90 minutes) for at least seven years prior to the study. All participants were asked to complete a detailed questionnaire using an online survey software covering history of prior musculoskeletal lower limb injuries associated with physical training for the last two years. Anatomical location and the main symptoms experienced of all reported illnesses were reported. Based on information collected from this questionnaire, participants were assigned to one of two groups: participants with self-reported lower limb musculoskeletal injuries in the last two years (IG; n=16; 26.9 ± 1.1 years old; 181.0 ± 6.8 cm; 77.9 ± 6.4 kg) and uninjured group (NIG; n=14; 27.4 ± 2.0 years old; 176.3 ± 6.3 cm; 78.1 ± 1.3 kg). IG reported knee joint injuries (LCA rupture, patellofemoral syndrome), pulled hamstring, shin splint and ankle sprain.
Participants were evaluated in five visits to the laboratory with 48hrs-72hrs of interval (Figure 1) and they were asked to refrain from strength or power training 24hrs prior to each session. On the first visit, body composition was evaluated by bioelectrical impedance analysis (InBody 270, USA). Moreover, a sit-and-reach test was conducted using the Wells box (SANNY, Brazil).

On the second visit, participants were familiarised with the vertical jump tests (Squat Jump - SJ- and Countermovement Jump - CMJ) and dynamic strength measured by 1 repetition maximum (1RM) in a smith machine (Tecknogym, Italy).

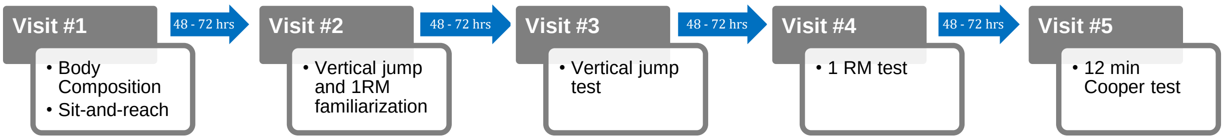

Figure 1 – Timeline of test procedures

On the third visit, squat (SJ) and countermovement (CMJ) jump was collected. Participants warmed-up by pedalling on a stationary cycle ergometer (Star Trac, EUA) followed by five sub-maximal jumps. Three SJ and three CMJ jumps with maximal effort was collected sequentially on the force platform (Bertec, USA) with a 1min rest interval between jumps. Participants were asked to keep their hands on their waist throughout the jumps and the order of SJ and CMJ was counterbalanced between participants. On the fourth visit, the Smith machine 1RM was evaluated. Participants ran for 5min on a treadmill at 9km/h, followed by 5min of lower limb stretching exercises and two back squat warm-up sets on the Smith machine. Three minutes later, the 1-RM test commenced with a load of approximately 90% of the participant's body mass. Participants had up to five attempts to achieve the squat 1RM with strong verbal support. On the fifth day, a 12min Cooper running test was performed on a 400m athletics track. Participants warmed up for 10min including both aerobic activities and flexibility exercises. A prediction of $\dot{V}O_2max$ from the distance covered at the end of the 12min period was obtained using the table provided by Cooper (1968).
A custom-written MATLAB 20.0 routine (The MathWorks, USA) processed the vertical jump data. Raw GRF was used to calculate jump height by the impulse-moment method (Linthorne, 2001) and landing peak. Peak power and peak rate of force development (PRFD) was obtained by the smoothed (12 Hz low pass Butterworth filter) GRF signal. Only the highest SJ and CMJ was considered. The Shapiro-Wilk's method was used to test the normality of the variables. Independent t-test was used to compare outcomes between groups for normally distributed variables. The Mann-Whitney U test was used to compare differences between non-normal distribution data (i.e. PRFD and landing peak of CMJ). Statistical analyses were performed in the SPSS 20.0 (IBM, USA). The significance level was set at $\alpha<0.05$ and magnitude of differences was calculated using Cohen's effect size (d).

RESULTS: Groups were not different in terms of flexibility, body composition and $\dot{V}O_2max$ (Table 1). However, groups presented statistical difference at 1RM and vertical jump variables (Table 1). IG subjects presented lower strength and PRFD on CMJ, as well as lower height and landing peak on SJ.

DISCUSSION: Participants from IG presented reduced lower back squat strength compared to NIG. As shown in a recent meta-analysis, resistance training-based sports injury prevention programs reduced injuries on average by 66% compared with prevention programs without a muscular strength focus (Lauersen et al., 2018). Therefore, it seems possible that participants in the IG need to regain strength.
The force plate variables collected from vertical jumps were able to identify differences in participants who sustained a lower limb injury, which aligns with findings from a previous study (Pontillo et al., 2021). PRFD in the CMJ was lower in IG compared to NIG which represents limited ability to develop force rapidly during dynamic concentric contractions in the injured group. Such variable can effectively discriminate between good and poor sprinter performers (Wilson et al., 1995). SJ height was also lower in the IG, which is in line with a previous study that observed a strong correlation with maximal strength and squat jump height (Wisløff et al., 2004). Taken together, the injured group presented reduced vertical jumps performance. This may have implications in their training regimen and potentially increase the risk of new injuries

if these participants are challenged beyond their physical capabilities. Although body composition variables did not present any significance difference, strength and jump power are directly associated with lean body mass (Bartolomei et al., 2021). These results suggest that reduced back squat strength and vertical jump performance in the IG could be more due to loss of neuromuscular coordination than muscular volume. However, further analysis looking at muscle volume may help further this element. Previous investigation observed a decreased functional capacity after an injury that could increase risk factor for future secondary injuries (Hägglund et al., 2006). It may be possible that, even though tissue healing has been completed in the IG, these subjects were not fully rehabilitated. These participants may still present signs of kinesiophobia (Huang et al., 2019) or diminished voluntary neural output (Hopkins & Ingersoll, 2000). Therefore, future research is warranted to provide intervention programs to reduce the fear of pain in individuals with a history of injury.

Table 1 – Body composition, flexibility, $\dot{V}O_2$max, vertical jump variables.

	IG	NIG	p-value	d
Lean Body Mass (kg)	38.6 ± 6.4	38.5 ± 3.4	0.114	0.019
Fat Body Mass (kg)	10.5 ± 3.8	10.8 ± 2.8	0.248	0.089
Fat-free Mass (kg)	67.5 ± 1.1	67.0 ± 5.7	0.115	0.121
% Fatness	13.3 ± 4.1	13.8 ± 3.3	0.698	0.134
$\dot{V}O_2$ max. (mlO$_2$/kg/min)	57.7 ± 3.1	58.2 4.4	0.788	0.131
Squat strength (kg)	111.4 ± 14.1	125.5 ± 16.6	***0.017****	0.915
Relative Squat strength (% BM)	1.43 ± 0.18	1.61 ± 0.23	***0.023****	0.871
Sit and reach flexibility (cm)	29.1 ± 8.8	28.3 ± 10.6	0.830	0.082
CMJ height (cm)	32.1 ± 3.6	36.1 ± 5.2	0.054	0.894
Peak Power CMJ (W/%BW)	5.2 ± 0.7	5.3 ± 0.7	0.935	0.142
PRFD CMJ (%BW/s)	11.2 ± 4.0	14.4 ± 6.4	***0.047****	0.599
Amortization Fz CMJ (% BW)	5.4 ± 1.8	6.9 ± 3.0	0.313	0.606
SJ height (cm)	30.3 ± 3.3	33.5 ± 4.1	***0.030****	0.853
Peak power SJ (W/%BW)	5.2 ± 0.5	5.5 ± 0.7	0.160	0.493
PRFD SJ (%BW/s)	11.4 ± 2.8	13.4 ± 4.3	0.252	0.560
Amortization Fz SJ (% BW)	5.2 ± 1.7	7.3 ± 2.3	***0.008****	1.036

* $p < 0.05$

Re-injury was suggested to be associated with deficits in neuromuscular outcomes (Fulton et al., 2014). A comprehensive rehabilitation program that uses the theory of regional interdependence to adequately mitigate local, proximal, and distal deficits in strength, proprioception, and lower extremity mechanics (Wainner et al., 2007) could be beneficial for individuals with lower limb musculoskeletal injury. Therefore, developing rehabilitation programs that address these limitations is important, and it may be possible to remove the previous injury risk factor component (Fulton et al., 2014).
All participants presented an excellent maximum oxygen output (ACSM, 2018) without cardiorespiratory fitness difference between groups. These results suggest that participants with a history of injuries were not limited in their cardiorespiratory fitness. Unlike previous studies that found reduced physical activity level in patients who have sustained an ankle or knee injury (Barchek et al., 2020), it seems possible that the requirements of the ongoing military training resulted in the IG sustaining appropriate levels of physical activity.

CONCLUSION: Militaries with a history of injury in the last two years presented reduced strength and vertical jump performance compared to uninjured participants. No differences in body composition or level of cardiorespiratory fitness were observed. It is possible that rehabilitation from injury may not have been sufficient to regain strength and power in this population and further work is required looking at signs of kinesiophobia and diminished voluntary neural output.

REFERENCES

ACSM. (2018). *ACSM Guidelines for Exercise Testing and Prescription* (10th ed.). Wolters Kluwer Health.

Barchek, A. R., Baez, S. E., Hoch, M. C., & Hoch, J. M. (2020). The relationship between musculoskeletal injury and objectively measured physical activity levels: A critically appraised topic. *Journal of Sport Rehabilitation*, *29*(2), 243–247. https://doi.org/10.1123/JSR.2018-0486

Bartolomei, S., Grillone, G., Di Michele, R., & Cortesi, M. (2021). A Comparison between Male and Female Athletes in Relative Strength and Power Performances. *Journal of Functional Morphology and Kinesiology*, *6*(1), 17. https://doi.org/10.3390/jfmk6010017

Cassel, M., Müller, J., Moser, O., Strempler, M. E., Reso, J., & Mayer, F. (2019). Orthopedic injury profiles in adolescent elite athletes: A retrospective analysis from a sports medicine department. *Frontiers in Physiology*, *10*(MAY), 1–10. https://doi.org/10.3389/fphys.2019.00544

Cooper, K. H. (1968). A Means of Assessing Maximal Oxygen Intake. *Jama*, *203*(3), 201. https://doi.org/10.1001/jama.1968.03140030033008

Fulton, J., Wright, K., Kelly, M., Zebrosky, B., Zanis, M., Drvol, C., & Butler, R. (2014). Injury risk is altered by previous injury: a systematic review of the literature and presentation of causative neuromuscular factors. *International Journal of Sports Physical Therapy*, *9*(5), 583–595. http://www.ncbi.nlm.nih.gov/pubmed/25328821%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4196323

Hägglund, M., Waldén, M., & Ekstrand, J. (2006). Previous injury as a risk factor for injury in elite football: A prospective study over two consecutive seasons. *British Journal of Sports Medicine*, *40*(9), 767–772. https://doi.org/10.1136/bjsm.2006.026609

Hopkins, J. T., & Ingersoll, C. D. (2000). Arthrogenic muscle inhibition: A limiting factor in joint rehabilitation. *Journal of Sport Rehabilitation*, *9*(2), 135–159. https://doi.org/10.1123/jsr.9.2.135

Huang, H., Nagao, M., Arita, H., Shiozawa, J., Nishio, H., Kobayashi, Y., Kaneko, H., Nagayama, M., Saita, Y., Ishijima, M., Takazawa, Y., Ikeda, H., & Kaneko, K. (2019). Reproducibility, responsiveness and validation of the Tampa Scale for Kinesiophobia in patients with ACL injuries. *Health and Quality of Life Outcomes*, *17*(1), 1–8. https://doi.org/10.1186/s12955-019-1217-7

Knapik, J. J., Jones, B. H., & Steelman, R. A. (2015). Physical Training in Boots and Running Shoes: A Historical Comparison of Injury Incidence in Basic Combat Training. *Military Medicine*, *180*(3), 321–328. https://doi.org/10.7205/milmed-d-14-00337

Lauersen, J. B., Andersen, T. E., & Andersen, L. B. (2018). Strength training as superior, dose-dependent and safe prevention of acute and overuse sports injuries: A systematic review, qualitative analysis and meta-analysis. *British Journal of Sports Medicine*, *52*(24), 1557–1563. https://doi.org/10.1136/bjsports-2018-099078

Linthorne, N. P. (2001). Analysis of standing vertical jumps using a force platform. *American Journal of Physics*, *69*(11), 1198–1204. https://doi.org/10.1119/1.1397460

Pontillo, M., Hines, S. M., & Sennett, B. J. (2021). Prediction of ACL Injuries from Vertical Jump Kinetics in Division 1 Collegiate Athletes. *International Journal of Sports Physical Therapy*, *16*(1), 156–161. https://doi.org/10.26603/001c.18819

Wainner, R. S., Whitman, J. M., Cleland, J. A., & Flynn, T. W. (2007). Regional interdependence: A musculoskeletal examination model whose time has come. *Journal of Orthopaedic and Sports Physical Therapy*, *37*(11), 658–660. https://doi.org/10.2519/jospt.2007.0110

Wilson, G. J., Lyttle, A. D., Ostrowski, K. J., & Murphy, A. J. (1995). Assessing dynamic performance: A comparison of rate of force development tests. *Journal of Strength and Conditioning Research*, *9*(3), 176–181. https://doi.org/10.1519/00124278-199508000-00010

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, *38*(3), 285–288. https://doi.org/10.1136/bjsm.2002.002071

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