EFFECTS OF LOAD CARRYING TRAINING ON CORE STRENGTH, BALANCE AND JUMPING MECHANICS OF FEMALE RESERVE OFFICER TRAINING UNIT CADET

Siti Hawa Zulaikha Jaapar dan Shazlin Shaharudin*

Pusat Pengajian Sains Kesihatan, Universiti Sains Malaysia, Malaysia

*Email: shazlin@usm.my

Abstract

Carrying a backpack imposes stress on the back and lower limbs. In Reserve Officer Training Unit (ROTU), carrying a backpack is a requirement. It is included in the training drafted by the Malaysian Armed Forces. This study examined the effects of weight training on core strength, balance and jumping mechanics in 20 female ROTU cadets (Backpack group = 10, Control group = 10). Both groups underwent six weeks of physical training twice a week, performing a 2.4 km run, three sets of jumping jacks (20 reps each set) and three sets of squats (10 reps each set). During physical training, the Backpack group carried a military issue backpack with a total weight of 7 kg, while the Control group carried nothing. Four tests were conducted prior and after the training sessions which were, Modified Plank test to assess core strength; Balance Error Scoring System test to assess static balance; Star Excursion Balance test to assess dynamic balance and Drop Vertical Jump test to assess the jumping mechanics through the evaluation of Frontal Plane Projection Angle (FPPA) of the knee joint. There were no statistically significant differences in core strength (p-value = 0.353), static balance (p-value=0.458) and knee FPPA (p-value=0.681) when comparing between the two groups post-training. These results suggest that six weeks of training with a 7 kg-backpack does not have any major effects on the core strength, static and dynamic balance, and jumping mechanics of female ROTU cadets.

Keywords: Backpack training, biomechanics, lower limb, military cadet

Introduction

The Reserve Officer Training Unit (ROTU), known as Pasukan Latihan Pegawai Simpanan (PALAPES), is a voluntary force that trains university students to become officers of Rejimen Askar Wataniah of the Malaysian Armed Forces. The community is encouraged to join the force to help defend the nation's strategic assets and the sovereignty. Hence, ROTU is considered a platform for the community to serve the country as volunteers.

The ROTU training involved three types of training: Localised Training, Continuous Training and Annual Camp Training. Localised training is conducted in the vicinity of university during semester, and the syllabus includes reading maps, using weapons and the components, and marching. Continuous Training is training that is conducted for more than 72 hours, and is usually held during semester break. The training includes compass marching and shooting exercises. Annual Camp Training includes Field Training Exercises (FTX) that comprises four phases of battle, which are advancing, attacking, defence and retreat. During Annual Camp Training, the cadets undergo technical and tactical tests. All this training requires endurance and strength; thus it is a must to do physical training at least for 45 minutes every day during Localised Training. The physical training constitutes of running and bodyweight exercises such as push ups, squat jumps, mountain climbers, and jumping jacks. Sometimes cadet officers are required to carry backpacks that are filled with sand weighted about 7 kg. Then, they run and do weight training such as isometric lift and push ups while wearing the backpack. This is to train them to the heavy weight of the backpacks that they will carry throughout FTX.

Regular load carriage activities are a key feature of military training programmes. Soldiers rely on their musculoskeletal system to support their body and additional load during movement (Brown, O'Donovan, Hasselquist, Corner & Schiffman, 2014). However, carrying weights on the back is associated with back pain, with 50% of adolescents reporting links of back pain to bag carriage (Dockrell, Kane & O'Keefe, 2006). The back pain may be resulted in the increased activity of the back muscles (Elfving, Dedering & Nemeth, 2003) which will cause muscular fatigue (Ibrahim, 2012). Furthermore, it has been shown that female adolescents have higher risk to back pain compared to male adolescents (Dockrell et al., 2006) which may be resulted from lower strength of the upper body in females (Haselgrove et al., 2008).

It is important for soldiers to have good locomotion in the battlefield, because any decrease in the capacity to walk and run can decrease their survivability. A study conducted among male military training students showed that weight distribution influenced static body balance (Park et al., 2014). The research studied the effects of weight distribution on armour wore by the subjects on body balance. They found that an even weight distribution tends to decrease the centre of pressure (COP) area and its medial-lateral trajectory despite a considerable weight difference, which helps to achieve better static balance (Park et al., 2014).

Rice, Fallowfield, Allsopp, and Dixon (2016) conducted a study on the effects of military load carriage activity on lower limb gait mechanics and muscle activities. The subjects

were asked to complete a 12.8-km course activity within 150 minutes, while carrying a Bergen (large rucksack), webbing (a belt to carry additional military kit) and a weapon. The total mass carried by the subjects was 35.5 kg. The study concluded that ground contact time was increased and sagittal plane lower limb mechanics were altered during loaded military training activity (Rice et al., 2016). Brown et al. (2014) conducted a study to compare lower limb biomechanics between heavy, medium and light load carrying. They found that the stance time was significantly longer during heavy load carrying compared to medium and light loads. Additionally, there was a decreased peak stance knee flexion angle and a greater hip adduction moment during heavy load compared to medium and light loads. Hence, lower limb biomechanics are important in identifying the modifications needed by the lower limbs, such as hip and knee flexion, as to enable good body balance. Therefore, the purpose of the present study was to investigate the chronic effects of load carrying training on balance, core strength and lower limb mechanics in female cadets.

Method

Study Participants

A priori sample size calculation of two-way ANOVA showed that a total of 24 participants (e.g., 12 participants per group) are sufficient to yield 0.8 power of the study with small effect size of 0.3. Sample size was calculated using G*Power Software version 3.1.9.2 (Heinrich Heine Universitat Dusseldorf, Germany). The participants comprised of ROTU cadet officers, with ages ranging between 19 – 25 years old, with normal body mass index and free from any lower limb and back injuries at the time of data collection. Those who were unable to complete at least 85% of the training programme, or had any injuries, or were pregnant or suspected pregnant were excluded from the research.

Participants were recruited voluntarily through advertisement and words of mouth. There were two groups of participants: (1) the experimental group that undergone physical training wearing backpacks (N=10); and (2) the control group that undergone similar physical training without wearing backpacks (N=10). The participants were weight-matched across the groups. The duration of participant involvement was six weeks. Participants were provided with details regarding the study methodology. Upon agreement, their consent was obtained. The protocol of this study was approved by Human Research Ethical Review Board of a local university (USM/JEPeM/16090319) in compliance with Declaration of Helsinki.

Study Design

This was an interventional study with pre- and post-intervention tests that compared the effects of physical training with weighted backpack across control and intervention groups. The participants went through a series of tests before and after physical training. The training was conducted twice a week for six weeks. Duration of each session was averaged 20 minutes. Both groups went through similar physical training regimens; however, only the intervention group carried a military issue backpack with a total weight of 7 kg during

the training. A session of the training programme include 2.4 km run, three sets of jumping jacks with 20 repetitions per set and three sets of squats with ten repetitions per set. Anthropometrics, core strength, static balance, dynamic balance and dynamic knee valgus during drop vertical jump were assessed both pre- and post-training.

Study Procedure

After obtaining participants' written informed consent, their anthropometric characteristics were measured. They were also asked to provide information about their medical history, other medical conditions, and any medications taking. A total of four tests were completed by the participants at pre- and post-training programme: (1) modified plank test; (2) Balance Error Scoring System (BESS) test; (3) Star Excursion Balance Test (SEBT) Test; and (4) Drop Vertical Jump (DVJ) test.

Modified Plank Test

This test measured the core strength of participants in terms of the duration that the participants could hold the plank position (Mackenzie, 2005). The participants started the test by holding a basic plank position, with the elbows right beneath the shoulders, the forearms as wide as the shoulders placed on the floor, and the toes on the floor.

Throughout the test, the participants were asked to maintain proper plank posture with the body parallel to the floor. If the hips were out of position or any other body parts other than the forearms and the toes touch the floor, the test was attenuated. The duration was recorded, which represented the stage that the participant completed before breaking their posture or dropping to the floor. Tong, Wu and Nie (2014) demonstrated that this test is highly reliable with an intraclass correlation (ICC) of 0.97. They also suggested that this test was a valid tool to assess global core muscle endurance.

Next, static balance was determined using Balance Error Scoring System (BESS) (Riemann, Guskiewicz & Shields, 1999). There are three stance positions in this test, which are (1) double-leg stance with feet together; (2) single-leg stance on the tested limb with the knee on the other leg in approximately 90º flexion; and (3) tandem stance whereby the foot of the tested limb in line and anterior to the foot of the other limb.

The order of the tested stance was double-leg stance, single-leg stance and tandem stance. Each position must be hold with eyes closed and hand on hips for 20 seconds, and stopwatch was used to evaluate the duration of the test. The scoring system was based on the errors done by the participant. There is a minimum score of zero and maximum score of 10. The total score was counted by adding the scores from the three stances (Onate, Beck & Van Lunen, 2007). The errors included were (1) eyes opened; (2) hands lifted from hip; (3) non-stance foot contacted the floor; (4) step, hop or other movement of the stance foot or feet; (5) forefoot or heel lifted; (6) hip moved more than 30° of flexion or abduction; and (7) remained out of position for longer than 5s. The researcher was the only scorer for the test. It was found that BESS had a moderate to good reliability in clinical evaluation of static balance (Bell, Guskiewicz, Clark & Pauda, 2011).

Drop Vertical Jump (DVJ) test was used to evaluate dynamic knee valgus of the participants (Munro, Herrington & Carolan, 2012). Participants stand with shoulder-width apart on a box with 30cm height. They were instructed to lean forward and drop from the box as vertically as possible, then immediately perform a maximal vertical jump, and finally landing back on the ground. There were no set instructions regarding arm movement, only for the participants to perform the jump naturally. Each participant performed three DVJs starting from a standing position, with one minute interval rest (Abd Rahman & Shaharudin, 2018). The jumps were captured from the frontal plane using digital camera (SONY HDR-CX240, Japan) and the knee frontal plane projection angle (FPPA) was analysed using Kinovea (version 0.8.15). Markers were attached at participant's anterior superior iliac spine (ASIS), centre of knee joint, tibia tubercle and centre of ankle joint. Knee FPPA was determined based on the intersection of lines created between ASIS and centre of knee joint, and tibia tubercle and centre of knee joint. This test demonstrated high reliability with a coefficient of more than 0.90, as found by Noyes, Barber-Westin, Fleckenstein, Walsh and West (2005).

Descriptive statistics was applied to analyse the mean and standard deviations for each variable in the four tests. Independent T-Test was applied to compare the differences across the intervention and control groups and Paired T-Test was applied to compare the differences within each group (e.g., pre and post intervention). A level of significance at $p<0.05$ was set for all the statistical analyses. Effect size (ES) to estimate the magnitude of the effect of training program was calculated based on Rhea (2004). Statistical tests were conducted using Statistical Package for the Social Sciences (SPSS) version 22.0 software.

Results

Anthropometric measurement of participants was presented in Table 1.

Table 1: Descriptive statistics (mean ± SD) of anthropometric measurement of participants (N=20)

	Backpack (N=10)	Control (N=10)	P-Value
Age	20.90 ± 0.316	20.50 ± 0.527	0.058
Weight (kg)	58.07 ± 9.209	55.09 ± 5.427	0.390
Height (cm)	158.45 ± 6.168	158.00 ± 3.621	0.844
Leg length of dominant leg (cm)	85.05 ± 3.811	85.10 ± 3.406	0.976

*kg = kilogramme; cm = centimetre; values in (mean ± SD)

Table 2 shows that there were no statistically significant differences in the duration of Modified Plank Test between groups, at pre- (p=0.219) and post-training (ES=0.432, p=0.353). However, when compared within groups from baseline values, only control group showed statistically significant differences (p=0.034) but not in the backpack group (p=0.094).

Table 2: Comparison of duration of Modified Plank Test across and within groups (N=20)

	Backpack (N=10)	Control (N=10)	P-Value Across Groups
Pre (s)	76.40 ± 26.61	63.30 ± 18.70	0.219
Post (s)	89.80 ± 26.52	80.80 ± 20.85	0.353
P-Value Within Groups	0.094	0.034*	

*s = seconds; values in (mean ± SD)

Table 3 shows that there were no statistically significant differences in the Balance Error Scoring System (BESS) scores between groups, at pre- (p=0.337) and post-training (ES=0.273, p=0.458). Within group comparison from baseline values, there were no statistically significant differences between the control (p=0.674) and backpack groups (p=0.223).

Table 3: Comparison of Balance Error Scoring System Scores across and within groups (N=20)

	Backpack (N=10)	Control (N=10)	P-Value Across Groups
Pre	2.80 ± 2.394	4.20 ± 3.795	0.337
Post	3.60 ± 2.011	4.60 ± 3.658	0.458
P-Value Within Groups	0.223	0.674	

*values in (mean ± SD)

Table 4 shows that there were no statistically significant differences of the frontal plane projection angle (FPPA) of the knee joint during Drop Vertical Jump test when comparing between groups, at pre- (p=0.393) and post-training (ES=0.176, p=0.681). Within groups comparison from baseline values, showed no statistically significant differences in control (p=0.056) and backpack groups (p=0.056).

Table Error! No text of specified style in document.**:** Comparison of knee frontal plane projection angle across and within groups (N=20)

	Backpack (N=10)	Control (N=10)	P Value Across Groups
Pre (°)	12.13 ± 5.203	10.13 ± 6.008	0.393
Post (°)	14.44 ± 6.474	15.74 ± 7.398	0.681
P-Value Within Groups	0.475	0.056	

*° = degree; values in (mean ± SD)

Discussions

In this study, 20 female Reserve Officer Training Unit (ROTU) cadets were recruited and divided into two groups: Backpack and Control. Their physical characteristics were measured prior to the training programme. There were no statistically significant differences in body height, weight and leg length between the two groups (Table 1). This comparison was done to ensure there were no biases that may influence their performance in the post-training programme.

Our results showed that there were no statistically significant differences in core strength before and after the intervention between groups (Table 2). However, there was a significant improvement of core strength in the control group at post-training compared to their respective baseline values. Based on our results, it can be observed that the backpack group had better core strength when compared to the control group at the baseline values, although this was not statistically significant. Therefore, a lack of significant changes in backpack group can be attributed to their greater core strength at the baseline level compared to the control group.

Lehman, Hoda and Oliver (2005) demonstrated that when performing a prone plank, the internal oblique, rectus abdominis, external oblique and erector spinae musculature elicited 29.5%, 26.6%, 44.6% and 4.98% of maximum voluntary contraction (MVC) respectively. As for carrying a backpack, Al-Khabbaz, Shimada and Hasegawa (2008) reported that the rectus abdominis muscles are activated, but not the erector spinae muscles. The centre of gravity of the body shifts backward and causes extra extension moment when carrying a backpack. This resulted in both sides of rectus abdominis muscles to contract more in order to balance the extra extension moment (Goh, Thambyah & Bose, 1998). We hypothesised that there should be an increase in the core strength of the backpack group following findings from previous studies. However, the current study did not evaluate muscle activity using EMG, instead core strength was evaluated using a functional test which may include influence from upper limb strength which was not ruled out. Hence, this could be a limitation in our study.

For the Balance Error Scoring System (BESS) test, smaller values of the score indicate better static balance. Table 3 showed that there were no significant differences across and within groups. The training programme in the current study involved major movement of the lower limbs. According to the principle of specificity, training adaptations are specific to the muscles trained during specific exercise prescribed (Hoffman, 2002). Moreover, training experiences and joint strength are likely factors that can contribute to better balance (Bressel, Yonker, Kras, & Heath, 2007). However, leg strength was not quantified in the current study; hence, the relationship between leg strength and balance was not able to be assessed. Furthermore, Aggarwal, Kumar, Kalpana, Jitender and Sharma (2010) reported that static balance was significantly correlated with core strength. In their study, core strength was evaluated using Prone Plank Test (Aggarwal et al., 2010). Corresponding to our core strength results obtained from Modified Plank Test, a lack of significant findings in static balance could be related to lack of significant improvement in core strength.

Based on our results, there were no significant changes in the knee frontal plane projection angle (FPPA) of female ROTU cadets after training programme with backpacks. The average knee FPPA angle during Drop Vertical Jump (DVJ) test for women is 7º to 13º (Herrington & Munro, 2010). Values exceeding the range indicate increased risk of non-contact knee injuries such as anterior crucial ligament (ACL) tear and patellofemoral pain syndrome (PFPS) (Hewett et al., 2005). Our pre-training results showed that female cadets from both groups had normal knee FPPA during DVJ (Table 4). However, after six weeks of training, the knee FPPA increased non-significantly in both groups.

Brown et al. (2014) reported that an addition of body borne load of 20kg and 40kg caused greater hip and knee flexion and hip adduction moments. Hip adduction moment is a factor for excessive dynamic knee valgus. The load used in the previous study (Brown et al., 2014) was heavier than the current study which was only 7 kg. Furthermore, Brown et al. (2014) studied the biomechanical factors while carrying backpack. As for the current study, the knee FPPA during DVJ test was conducted while the participants were not carrying backpacks following six weeks of training with 7 kg backpacks. This is because the objective of the current study was to evaluate the chronic effects of training with extra loads.

Not many studies were conducted on the chronic effects of carrying backpacks on lower limb biomechanical characteristics. Based on our results, there was a trend of FPPA increment following ROTU training with and without backpacks. Therefore, we should take precautions while carrying out ROTU exercises such as including hip strengthening exercises in ROTU exercise regimen to reduce the risk of lower limb injuries.

There are some practical applications that can be taken from this study. The Drop Vertical Jump test can be included in ROTU's fitness assessment, as a screening test for lower limb injuries such as ACL injury. Previous studies had demonstrated that a valgus alignment of the knee is commonly seen during non-contact ACL injuries (Noyes et al., 2005). This occurs when the person lands from a jump or either in an attempt to accelerate into a jump, which both motions are common in ROTU training.

Training with backpacks and carrying backpacks during Field Training Exercises (FTX) are two different things. During training, the weight of backpack is standardised to 7 kg, but during FTX the load may be more depending on the additional items that need to be carried such as weapons, extra clothing and food rations. Hence, strength training specifically in the core and hip musculature is crucial for reducing risks to any type of lower limb injuries.

This study is limited to a small sample size. The analysis of 2D FPPA angles of Drop Vertical Jump, may not as accurate as 3D motion analysis. In terms of core strength and balance during pre-training, participants in the Backpack group had non-statistically significant greater balance and core strength than the Control group. This is because the participants chose their group voluntarily in order to increase their compliance with the training sessions. Although the groups were matched in terms of their body weight, this may influence in a lack of statistically significant findings in post-training.

Recommendations for Future Study

The duration of the training program and the weight of the backpack may be increased to observe statistically significant findings in the same type of population. Other than that, fitness level of the participants is also an interesting variable to test, as extra load will cause more stress to the cardiovascular system. It is also recommended to try different types of exercise while carrying backpack to study the same variables in the study.

Conclusion

Six weeks of training with backpacks had no effects on core strength, static balance and knee FPPA during DVJ test. The duration of the prescribed training and the weight used in the current study may not sufficient to cause any significant effects on the tested variables. We can conclude that training while carrying backpacks is safe among female ROTU, but precautions need to be taken to reduce risks of non-contact lower limb injuries.

Acknowledgements

Conflicts of interest

None.

References

Abd Rahman, N. A., & Shaharudin, S. (2018). Comparison of skills and lower limb biomechanics of female futsal players at collegiate and club levels. *Malaysian Journal of Movement, Health & Exercise, 7* (2), 177-194.

Aggarwal, A., Kumar, S., Kalpana, Z., Jitender, M., Sharma, V. P. (2010).The Relationship between core stability performance and the lower extremities static balance performance in recreationally active individuals. *Nigerian Journal of Medical Rehabilitation, 15* (23),11-16.

Al-Khabbaz, Y.S.S.M., Shimada, T & Hasegawa, M,.(2008).The effect of backpack heaviness on trunk-lower extremity muscle activities and trunk posture. *Gait & Posture*, *28*, 297-302.

Bell, D.R., Guskiewicz, K.M., Clark, M.A., & Pauda, D.A. (2011). Systematic review of the balance error scoring system. *Sports Health*, *3*(3), 287-295.

Bressel, E., Yonker, JC., Kras, J., & Heath, E.M.(2007). Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of Athletic Training*, *42* (1), 42-46.

Brown, T.N., O'Donovan, M., Hasselquist, L., Corner, B.,& Schiffman, J.M. (2014). Soldier-relevant loads impact lower limb biomechanics during anticipated and unanticipated single-leg cutting movements. *Journal of Biomechanics*, *47*, 3494-3501.

Dockrell, S., Kane, C., & O'Keefe, E. (2006). Schoolbag weight and the effects of schoolbag carriage on secondary school students. *Ergonomics*, *9*, 216-222.

Elfving, B., Dedering, A., & Nemeth, G. (2003). Lumbar muscle fatigue and recovery in patients with long-term low-back trouble - electromyography and health-related factors. *Clinical Biomechanics*, *18*,   619-630.

Goh, J.H., Thambyah, A., & Bose, K. (1998). Effects of varying backpack loads on peak forces in the lumbosacral spine during walking. *Clinical Biomechanics, 13* (1), S26-S31.

Haselgrove, C., Straker, L., Smith, A., O'Sullivan, P., Perry, M., & Sloan, N. (2008). Perceived school bag load, duration of carriage, and method of transport to school are associated with spinal pain in adolescents: an observational study. *Australian Journal of Physiotherapy*, *54*,193-200.

Herrington, L., & Munro, A. (2010). Drop jump landing knee valgus angle; normative data in a physically active population. *Physical Therapy in Sport*, *11*, 56-59.

Hewett, T.E., Myer, GD., Ford, K.R., Heidt Jr, R.S., Colosimo, A.J., McLean, S.G., van den Bogert, A.J., Paterno, MV., & Succop, P. (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes *The American Journal of Sports Medicine, 33*(4), 492-501.

Hoffman, J. (2002). *Physiological aspects of sport training and performance.* Champaign, IL: Human Kinetics.

Ibrahim, A.H., (2012). Incidence of back pain in Egyptian school girls: Effect of schoolbag weight and carrying way. *World Applied Sciences Journal*, *17,* 1526-1534.

Lehman, G.J., Hoda, W., & Oliver, S. (2005). Trunk muscle activity during bridging exercises on and off a Swissball. *Chiropractic & Osteopathy, 13*, 1-8.

Mackenzie, B. (2005) *101 Performance evaluation tests*. London: Electric Word plc.

Munro, A., Herrington, L., & Carolan, M. (2012). Reliability of 2-dimensional video assessment of frontal-plane dynamic knee valgus during common athletic screening tasks. *Journal of Sports Rehabilitation*, *21*, 7-11.

Noyes, F.R., Barber-Westin, S.D., Fleckenstein, C., Walsh, C., & West, J. (2005). The drop-jump screening test – difference in lower limb control by gender and effect of neuromuscular training in female athletes. *The American Journal of Sports Medicine*, *33*(2), 197-207.

Onate, J.A., Beck, B.C., & Van Lunen, B.L. (2007). On-field testing environment and balance error scoring system performance during preseason screening of healthy collegiate baseball players. *Journal of Athletic Training*, *42* (4), 446-451.

Park, H., Branson, D., Kim, S., Warren, A., Jacobson, B., Petrova, A., Peksoz, S., & Kamenidis, P. (2014). Effect of armor and carrying load on body balance and leg muscle function. *Gait & Posture*, *39*, 430-435.

Rhea, M.R. (2004). Determining the magnitude of treatment effects in strength training research through the use of the effect size. *Journal of Strength and Conditioning Research, 18*(4), 918-920.

Rice, H., Fallowfield, J., Allsopp, A., & Dixon, S. (2016). Influence of a 12.8-km military load carriage activity on lower limb gait mechanics and muscle activity. *Ergonomics*, 1-9.

Riemann, B.L., Guskiewicz, K.M., & Shields E.W. (1999). Relationship between clinical and force plate measures of postural stability. *Journal of Sports Rehabilitation*, *9*, 71-82.

Tong, T.K., Wu, S., & Nie, J. (2014). Sport-specific endurance plank test for evaluation of global core muscle function. *Physical Therapy in Sport*, *15*, 58-63.