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Original Research

Aerobic Fitness is of Greater Importance than Strength and Power in the Load Carriage Performance of Specialist Police

JEREMY ROBINSON‡1, ADAM ROBERTS‡1, SHANE IRVING*1, and ROBIN ORR‡2

[1]Australian Federal Police, Canberra, ACT, AUSTRALIA; [2]Tactical Research Unit, Bond University, Gold Coast, QLD, AUSTRALIA

*Denotes undergraduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 11(4): 987-998, 2018. Police officers are required to carry external loads as part of their occupation. One means of preparing officers to carry loads is through physical conditioning. The aim of this study was to investigate whether strength, power or aerobic endurance had the greatest association with load carriage performance. Retrospective data from 42 male specialist tactical police officers (mean body weight = 88.8±8.25 kg) informed this study. Baseline data were provided for strength (1 Repetition Maximum [RM] bench press, deadlift, squat and pull-up), lower body power (vertical jump, 10m sprint) and aerobic ('beep' test) performance. In addition, officers completed three 5km load carriage trials (3 to 4 months apart) with 25 kg packs as fast as possible. Pearson's correlations were used to look for associations between measures with an analysis of variance used to detect changes in load carriage performance. Alpha levels were set a priori at 0.05. All variables of strength and power were significantly correlated with performance except for 1RM deadlift and the 10m sprint for the last two load carriage trails. Of all fitness measures, aerobic fitness was the most highly significant correlation with the load carriage trials (r=-0.712, -0.709 and -0.711 for trials respectively). Time to completion improved across the three load carriage trials (p<.001). These findings support the approach that optimal load carriage performance may be achieved by performing load carriage tasks in conjunction with aerobic fitness and full body strength / lower limb power training.

KEY WORDS: SWAT, law enforcement, pack march, tactical

INTRODUCTION

Tactical personnel, like those serving in the military, as fire fighters or in law enforcement, are required to carry external loads as part of their occupation. External loads were constructed from a combination of specialist weapons, body armor, communications equipment, flashlights, specialist breaching equipment and ballistic shields (2, 5, 6). In law enforcement, average duty belts can range in weight from 3.62 kg to 6.8 kg depending on what is being carried (7), while body armor can weigh from 3.8 kg to 6.1 kg (3, 6) and in some cases up to 17.0 kg (20). The combined weight of a duty belt and body armor can have the general duties police officers carry up to 10 kg of extra weight on their body (2, 21). In specialist personnel like special weapons and tactics (SWAT) officers and those required to wear chemical, biological, radiological and nuclear personal protective equipment (CBRN PPE), these loads are heavier and can range from over 22 kg to 27 kg (2, 5).

While these loads constitute vital equipment, for example body armor for protection, they can also be a source of risk to the officer. Research in specialist police populations has found that load carriage can have a negative impact on officer mobility with officers taking longer to cover terrain when carrying heavier relative loads (5). In a study of specialist police officers, officers were found be 10 % slower to rescue a victim (10m sprint and 10m victim drag of an 80 kg mannequin) when wearing external loads of up to 22.8 kg (5). In addition, officers carrying more than 25% of their body weight were even slower than those carrying less than 25% of their body weight (5). When it comes to the ability of officers to employ their personnel weapons, the carriage of these external loads may impact their marksmanship; although the evidence is conflicting. One study of specialist police officers found no significant difference in marksmanship when officers were tactically loaded (carrying 22.8 kg) (4). However, the aforementioned study had the specialist police officers employ their secondary weapon (Glock pistol) as opposed to their primary weapons (M4 Carbine). Considering this, while some studies of military personnel, have found that rifle marksmanship decreases following longer and heavier load carriage tasks (10, 12), this is not always the case (15). In the two studies identified in which load carriage did not significantly impact on marksmanship (4, 15), both studies utilized specialist officers and specialist soldiers as participants and their higher levels of fitness was thought to be a contributing factor to their ability to carry these external loads and still employ their weapons accurately (4).

Apart from impacting on performance, load carriage is known to cause injuries to tactical personnel. Injuries can range from blisters, to sprains and strains across a variety of bodily joints, to neurological injuries affecting the arm, thigh and foot (13, 16, 25). The impact of these loads can likewise vary. In a single march event of military personnel, Knapik (17) observed that while several different injuries were sustained, those who suffered foot blistering had the highest number of 'limited duties days' while half of those who suffered a back injury failed to finish the event. Considering this, research by Orr et al.,(23) found that soldiers who suffered an injury during a load carriage task were highly likely (42%) to suffer a further injury while performing load carriage tasks in their career.

One means of preparing officers to carry loads is through physical conditioning (14, 22). Research in military load carriage has identified that load carriage itself is a key means of developing this capability in these tactical populations (14, 22). Apart from load carriage, a combination of strength training and aerobic training, as opposed to either alone, is also noted as being effective (14, 22). What is not known however, is which parameters, strength, power or aerobic endurance, have the greatest influence on load carriage performance. Therefore, the aim of this research was to investigate whether strength, power or aerobic endurance has the greatest association with load carriage performance.

METHODS

Participants
Data from 42 male specialist tactical police officers from an Australian law enforcement service were provided in a non-identifiable format. Given the strict security protocols regarding the protective identity of these personnel no demographic data other than body weight (mean = 88.8 ± 8.25 kg) was provided. This limitation has been reported in previous research in law enforcement populations (24). Ethics approval for this research was provided by the Bond University Human Research Ethics Committee with research following carried out in accordance with the conditions of the Declaration of Helsinki: Recommendations Guiding Physicians in Biomedical Research Involving Human Subjects (28).

Protocol
Measures were collected over a period of two weeks with strength testing conducted over 2 days in the first week (Day 1 - Bench press and deadlift: Day 2 - Squat and pull-up) and the vertical jump (VJ), 10m sprint and beep test conducted over two days in the second week (Day 1 – VJ and 10m sprint: Day 2 - beep test). The four days of testing was due to the availability of specialist police personnel and the allocated time permitted in one session to conduct these physical tests. Following the establishment of the baseline measures, the specialist tactical police completed three load carriage marches with 25 kg packs over a distance of 5km as fast as possible. The marches were completed at three to four-month intervals in June 2011, September 2011 and January 2012. The protocols for the capture of these outcome measures are described below:

Strength measures: The one repetition maximum (1RM) test is a gold standard for assessing strength in non-laboratory situations (8). 1RM is defined as the maximal force a muscle or muscle group can exert for one single voluntary effort (1). The test also appears to be extremely diverse and can be conducted for a range of exercises (for example, squat, power clean and bench press) (1).

The 1RM protocol employed for the bench press, back squat and deadlift is described in Table 1 and for the overhand weighted pull-up in Table 2. These protocols were followed after a 10-min warm up on each day of testing. The warm up included self-selected, activation, movement and central nervous system exercise, including; lying supine glute bridges, side lying clam openers, Hindu pushups with rotation, bodyweight squats, single leg Romanian deadlift without resistance, clock pattern lunges, supine lying alternating leg lumbar rotations, alternating forward lunge with over hand reach above head, clap pushups and 5-10 kg medicine ball slams.

The bench press: The bench press test was conducted utilising a 20 kg Pendaly Brand Barbell, Garage gym brand bumper weight plates and Hammer Strength Bench support. The bench press technique required each specialist police officer to start by lying flat on a bench, with their feet flat on the floor and buttocks and shoulder blades touching the bench. The bar was grasped at slightly wider than shoulder width apart (so that the elbows were at right angles at the lowest point). The 1RM test began with the officer removing the weight from the rack supports with their arms fully extended, holding the weight directly above the chest. The weight was lowered at a controlled speed and with a smooth motion, to just touch the chest then returned to the starting position to complete the repetition. One Strength and Conditioning (S&C) coach was utilized as a spotter and recorder for this test.

Table 1. 1RM protocol of the bench press, back squat and deadlift. Adopted from National Strength and Conditioning Association (1).

Set	Weight	Reps	Rest
1	50% of self-predicted 1RM	10	1min
2	80% of self-predicted 1RM	5-6	2min
3*	Near maximal load.	3	2min
4	Attempt 1	1	3min
5	Attempt 2	1	4min
6	Attempt 3	1	4min

* Note for upper body strength tests a 5-10% increase from set 3 was recommended and 10-20% increase for lower body exercise tests. After each successful performance from set 4, the weight increased until a failed attempt occurred.

Table 2. 1RM protocol for the overhand weighted pull-up.

Set	Weight	Reps	Rest
1	Bodyweight	5	1min
2	Self-selected load	4	2min
3	Near maximal load.	3	2min
4*	Attempt 1	1	3min
5	Attempt 2	1	4min
6	Attempt 3	1	4min

* After each successful performance from set 4, the weight increased by 5-10% until a failed attempt occurred.

The back squat: The back squat test equipment utilized was a 20 kg Pendaly Brand Barbell, Garage gym brand bumper weight plates and Hammer Strength Power Rack. The officer was instructed to step under the bar which was positioned in the supporting arms within the Hammer Strength Power Rack. The officer then positioned the barbell onto their upper back above the horizontal aspect of the trapezius, hand grip slightly wider than shoulder width or positioned to suit the individual's mobility with hand spacing. The stance and feet position was just outside shoulder width apart. On command, the officer removed the weighted barbell from the rack supports and on instruction took two steps back and performed the eccentric movement of the squat to a sufficient depth whereby the central line of the femur was parallel to the ground before concentrically performing a full extension of the hip and knee joint. Two S&C coaches were utilized during this test as spotters.

The deadlift: One Australian Barbell Company diamond-shaped bar (weighing 24 kg) and Garage gym bumper weight plates were utilized on a rubber mattered area of gym flooring for the deadlift 1RM test. The officer was instructed to stand inside the diamond-shaped bar with their feet shoulder-width apart, squat and grasp the bar while their head remained in a neutral position and their heels remained flat on the ground. The lift began with the officer's arms at their sides and fully extended. When given the commands by the S&C coach, "Ready" and "Lift" the officer lifted the bar upwards by extending the hips and knees in a slow, continuous movement at the same time. When the officer was standing with their hips and knees fully extended the S&C coach said, "Down". The officer would then place the bar on the ground in a controlled manner. If an officer displayed poor lifting technique, they were stopped immediately and did not receive a result for the lift.

The 1RM pull-up: The pull-ups were conducted with a pronated grip (back of hands facing towards the officer) with a grip-width wider than shoulder width in order to allow a 90 degree angle when the upper arms were parallel to the ground. Legs were bent at the knee at 90 degrees with ankles crossed over behind the body. A weight belt (Dan Baker strength) was used and selected weight plate/s were position to hang in front of body. No swinging of the legs was allowed during the pull-up movement. During the concentric phase of the pull-up, the officer's chin was required to be raised above the bar which constituted a successful repetition. The officer performed pull-ups while under load per the following protocol described in Table 2. Combining the officer's bodyweight plus the weight lifted during the pullup gave the total 1RM weight lifted.

Power and aerobic fitness measures: The VJ power and aerobic fitness measures were conducted following a 5-min (Day 1) or 12-min (Day 2) warm up period again consisting of self-selected activation and movement. Examples of the exercises include a wall stretch with glute lifts (4 x 2-sec holds), crook lying hip lifts (2 x 8-reps each leg), ankle rocks (5 reps each foot) and short shuttle runs (10m) progressively increasing in speed.

The vertical jump (counter movement jump): As with previous research in this population (24), each officer was given two attempts to record their best VJ height using a counter movement jump technique. The officers were instructed to stand with their side to a wall and reach up with their hand closest to the wall. Keeping their feet flat on the ground, the point of the officer's fingertips was marked and recorded (in cm) as standing reach height. The officer then stood slightly away from the wall, and performed a counter movement jump, by bending the knees immediately prior to the jump and using both arms assisting to project the body upwards. The officers were instructed to touch the wall at the highest point of the jump. The difference in distance between the standing reach height and the jump height was the recorded score. The best of 2 attempts was recorded in cm with a 2-min recovery time allocated between attempts.

The 10m sprint: The 10m sprint was conducted on a concrete surface with the 10m distance marked out using a measuring tape (30m Fiber Glass Hart Sport) and distances marked with 2 markers identifying start and finish points. The officer started in a split stance position with one leg forward, one leg back and were instructed to start in the same split stance position for their second attempt (i.e. not to change legs). A verbal countdown was given as a 3-2-1 command followed by a single whistle blast to signify the start of the test. As electronic timing gates were not available at the time for the tests, sprint time was measured using a hand held stopwatch. The time was recorded in seconds by a S&C who was situated at the 10m finish marker. Each 10m sprint was separated by a 2-minute rest with 2 attempts performed for best result recorded.

The 'beep' test (20m progressive shuttle run test): The beep test was conducted on a flat, concrete, non-slip, surface with a 20m distance between two identifiable cones marked out with a measuring tape (30m Fiber Glass Hart Sport). The beep test intervals were governed by an audio compact disc from the Australian Sports Commission with each level progressively increasing in speed. The officers were instructed that the test was an 'individual maximal aerobic power running test' and that they were required to run towards the opposite 20m line and reach that line before the next successive beep (preferable in time with the successive beep). This constituted completion of a successful 'shuttle'. They were then required to return to the original line within the sound of the following beep. This same pattern was to be performed continuously, with successive increases in speed between levels until they reach voluntarily exhaustion. If the officer failed to reach the opposite line before the 'beep', the officer was issued with one fail attempt. If they recorded two consecutive fail attempts, they were withdrawn from the test and their score (Level and shuttle number) were recorded. However, if the officer reached the next line before the second consecutive beep, their fail attempts were reset.

Pack march protocol 5km: Prior to the pack march all officers' individual body weights were taken (Tanita BC82Fitplus scales) without footwear. The dress for the test was issued operational camouflage uniform and boots. Each of the officers' individual operational backpacks were weighed (Wedderburn Ds-530 Digital Industrial scale) to ensure a load of 25 kg. The primary weapon carried was unloaded and weighed 3.6 kg. The 5km pack march route was conducted on a flat surface that was a combination of bitumen and hard dirt. The route was marked out using a Garmin Oregon 600t handheld GPS. The route undertaken for the test was not provided due to security reasons for operational training location. The officers were instructed that they were allowed to jog during the test when required as this may be expected during tactical movements operationally. The time to complete the 5km was recorded on a Hart Sports hand held timer by an S&C coach.

Statistical Analysis

Data were provided in a spreadsheet before being imported into SPSS (v23) for analysis. To investigate whether any relative strength relationships existed with load carriage performance, all strength measures were also divided by participant body weight to determine relative strength ratios. Following descriptive analysis, Pearson's correlations were performed to investigate associations between measures of the baseline data (both absolute and relative strength, lower body power, and aerobic measures) and all three load carriage performances. An *a priori* power analysis conducted using G*Power software (version 3.1.9.2, 2014) indicated that these participant numbers would detect a large effect size ($p=.5$, $\alpha=0.05$) with a statistical power of 0.95 for the Pearson's correlations between measures.

To investigate changes in load carriage performance over time, an Analysis of Variance (ANOVA) was performed with a Bonferroni post hoc analysis to determine where any significances lay. An *a priori* power analysis conducted using G*Power software (version 3.1.9.2, 2014) indicated that these participant numbers would yield a statistical power of 0.95 to detect a small to medium effect size (Cohen's f = .15, alpha = 0.05) in the repeated measures ANOVA to be conducted to assess differences within participants between march events in march time. Finally, the variable with the highest correlation to performance was entered into a linear regression for each of the three load carriage march performances in order to provide potential predictive equations. Alpha levels were set *a priori* at 0.05.

RESULTS

Data were available for 42 male officers (mean body weight = 88.84±8.25 kg) with no data removed from analysis. The descriptive data for each measure is shown in Table 3.

Table 3. Descriptive data for all measures.

Measure	Mean ± Standard Deviation
1RM Bench Press (kg)	109.67 ± 19.80
Bench Ratio (%)	1.24 ± 0.20
1RM Squat (kg)	125.79 ± 24.53
Squat Ratio (%)	1.42 ± 0.25
1RM Deadlift (kg)	151.64 ± 26.31
Deadlift Ratio (%)	1.71 ± 0.25
1RM Pullup (kg)	121.43 ± 14.91
Pullup Ratio (%)	1.37 ± 0.15
Vertical Jump (cm)	50.21 ± 5.88
10m (secs)	1.88 ± 0.10
Shuttle Run (Level)	11.30 ± 1.07
Pack March 1 (mins:sec)	44.00 ± 1.50
Pack March 2 (mins:sec)	43.12 ± 1.76
Pack March 3 (mins:sec)	42.48 ± 1.99

Table 4. Correlations between load carriage performance and all baseline measures.

Measure	Pack March 1	Pack March 2	Pack March 3
Pack March 1 (mins:sec)	1	.840**	.815**
Pack March 2 (mins:sec)	.840**	1	.881**
Pack March 3 (mins:sec)	.815**	.881**	1
Body Weight (kg)	.097	.010	.081
1 RM Bench Press (kg)	-.360*	-.318*	-.295*
Bench Ratio (%)	-.465**	-.365**	-.379**
1 RM Squat (kg)	-.401**	-.335*	-.316*
Squat Ratio (%)	-.500**	-.381**	-.396**
1 RM Deadlift (kg)	-.288*	-.248	-.215
Deadlift Ratio (%)	-.403**	-.294*	-.305*
1RM Pull-up (kg)	-.452**	-.439**	-.416**
Pull-up Ratio (%)	-.607**	-.512**	-.541**
Vertical Jump (cm)	-.501**	-.541**	-.523**
Shuttle Run (level)	-.712**	-.709**	-.711**
10-meter Sprint	.373*	.178	.217

* Correlation is significant at the 0.01 level (2-tailed).

** Correlation is significant at the 0.05 level (2-tailed).

The Pearson's correlations (Table 4) between fitness measures and pack march performance ranged from a weak (r=0.178) and not significant (p=.243) correlation for the 10m sprint to a strong (r=-0.712) and significant (p<.001) negative correlation for the shuttle run test. Of note, almost all other variables of strength and power were significantly correlated with performance with the all the relative strength measures displaying a slightly greater correlation with load carriage performance than the absolute strength measures.

The results of the ANOVA identified that the load carriage march time to completion improved across the three trials (F[2, 138]=8.824, p<.001) with the Bonferroni post hoc analysis identifying fastest times between the second (43:12 mins, p<0.049) and third (42:48 mins, p<0.001) march when compared to the first march (44:00 mins). Interestingly, as the speed of march increased there appeared to be a decrease in the level of correlation between the strength measures and the pack march times. However, there were no differences in levels of correlation between the shuttle run levels and all three of the load carriage marches even with the decrease in march time (r=-0.712, -0.709 and -0.711 respectively) (See Figure 1).

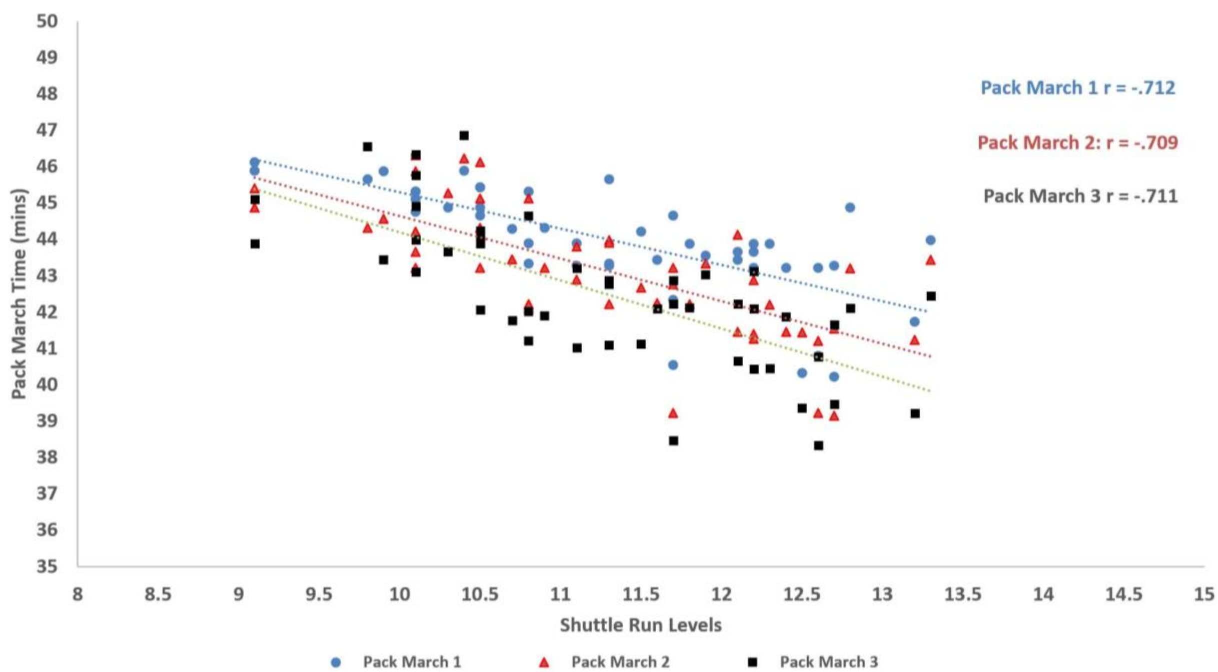

Figure 1. Graphical representation of the relationship between shuttle run levels and pack march times for all three pack march events.

DISCUSSION

The aim of this research was to investigate whether strength, power, or aerobic endurance had the greatest association with load carriage performance. The results of this study suggest that measures of strength were generally significantly and moderately correlated with load carriage performance. However, aerobic fitness, as measured by the beep test, had the strongest, significant correlation with all three load carriage events.

These results suggest that both strength/power and aerobic fitness are associated with load carriage performance. These findings are indirectly supported by the outcomes of several literature reviews and individual studies investigating optimal conditioning requirements for load carriage performance. Two literature reviews of research investigating the optimal means of physically conditioning soldiers for load carriage by Knapik et al., (14) and Orr et al., (22) found that a combination of resistance and aerobic training had a positive impact on load carriage performance as opposed to either approach in isolation. Furthermore, this combined training approach was enhanced by including load carriage tasks as part of the conditioning program.

Kraemer and Colleagues (18, 19) conducted two studies employing physical training protocols which included resistance training (full body or upper body), and aerobic training (long distance running and sprint intervals), either in combination or in isolation. The results from these two studies (12 week program of male soldiers training four times a week (19): 24 week program of untrained females training three times a week (18)) found that the conditioning programs that employed a combined training approach of both resistance training and aerobic training were associated with significant improvements in loaded 3.2km run (44.7 kg load) completion time whereas those studies where the participants followed either a resistance training (19) or aerobic training (18, 19) program in isolation failed to make any significant improvements in loaded run times. Given the requirement to include both strength and aerobic fitness training to optimize load carriage performance, the correlation between strength, aerobic fitness and load carriage performance found in this study these findings were not unexpected.

Of interest in this study was the high correlation between upper body strength measures (1RM pull-ups and 1RM bench press) and loaded march performance, most notably in the 1RM pull-ups ratio (r=-.512 to -.607). Similarities are again found when considering the impacts of conditioning on load carriage performance, whereby even in a program employing only upper body resistance training combined with endurance training (19), improvements were made in loaded run time performance. In this instance Kraemer et al., (19) purposed that upper body strength, which in turn improves posture maintenance, lead to an increase in energy efficiency and hence aided in improving load carriage task performance.

Regarding the relationship between strength measures and load carriage performance, it appears that relative measures (i.e. in relation to the lifter's body weight) are more highly correlated with load carriage performance than absolute strength measures. These results may be explained by the nature of the load carriage task whereby the load carrier must propel both their own body weight (relative) and that of the external load (absolute). This relationship between carrier's load and absolute load is well acknowledged in research designed to predict the metabolic coasts of carrying given loads (9, 26). On this basis, it would appear that both absolute and relative strength are important to load carriage performance, although at the loads investigated in this study, relative strength may be slightly more so.

Considering these findings, one study by Hendrickson et al.,(11) found significant improvements in a 3.2km loaded run (32.7 kg backpack) in an aerobic training only group (13 recreationally active women) while failing to find significant improvements in the resistance training only group (18 recreationally active women). Again however, the combined resistance training and aerobic training group (15 recreationally active women) yielded a greater improvement when compared to aerobic training alone (13.1% versus 12.9%).

The relationships between aerobic fitness and load carriage is supported by improvements in oxygen consumption found following load carriage training in a study by Rudzki (27). In this study, Rudzki (27) compared a weight load marching group (n=48) to a running group(n=46) in Australian Army recruits undergoing basic training. The study found that if the load carried (21.2-29.0 kg) and speed of march (7.5km/h) were sufficient, the oxidative capacity of soldiers increased to the same extent as those soldiers who undertook run training. This finding highlights the potentially high oxidative requirement of load carriage tasks and can help explain why in this study, oxidative performance was more highly correlated than measure of strength to load carriage performance.

The aforementioned study by Rudzki (27) also noted that the soldiers who undertook weight loaded walking were better able to cope with military tasks (which included load carriage) when compared to the running group. This finding by Rudzki (27)as well as the findings that combined aerobic and resistance training programs yielded better improvements in load carriage events if the program included load carriage training fits with the concept of specificity. The principle of specificity, which has as its underlying tenant the that adaptations are specific to the nature of the training stress (29), infers that load carriage activities are needed to optimally improve load carriage performance. This principle helps to explain the findings of this study whereby load carriage performance was most strongly correlated with load carriage performance, be it previous or future.

The findings of this study suggest that load carriage performance is the most highly correlated to future and previous load carriage performances, closely followed by aerobic fitness. While strength is still significantly correlated, relative strength measures appear to be of greater association with load carriage performance and as such should be a considered means of strength conditioning. These findings support the approach that optimal load carriage performance may be achieved by performing load carriage tasks in conjunction with aerobic fitness and full body strength / lower limb power training. Furthermore, previous aerobic fitness assessment performance can be used to inform future load carriage sessions.

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