

THE IMPACT OF LOAD CARRIAGE ON LOWER-BODY POWER IN SWAT POLICE

Robin Orr, PhD

Tactical Research Unit, Bond University, Queensland, Australia

Filip Kukić, PhD¹

Testing Section, Police Sports Education Center, Abu Dhabi Police, UAE

Eduardo Marins

Federal University of Pelotas, Rio Grande do Sul, Brazil

Cheryl Lim

Centre of Excellence for Soldier Performance, Singapore

Jay Dawes, PhD

Department of Health and Human Performance,
Oklahoma State University, Stillwater, Oklahoma, USA

Robert Lockie

Center for Sport Performance, Department of Kinesiology,
California State University, Fullerton, California, USA

Abstract: Tactical personnel such as Special Weapons and Tactics (SWAT) police are required to carry occupational loads of approximately 20 kg and, on occasion, more than 40 kg. These occupational loads have been found to negatively impact officer mobility. The aim of this study was to investigate the impact of load carriage on lower-body power in SWAT Police.

Six active male officers of a state police SWAT unit (mean age = 34.0 ± 7.4 years, mean height = 184.2 ± 3.3 cm, mean body mass = 96.3 ± 6.4 kg, mean years of SWAT experience = 6.0 ± 6.8 years) volunteered to participate. Ethics approval for the study was obtained by Bond University Human Research Ethics Committee (RO1585). Lower-body power was measured using a repeated vertical jump (VJ) test of three jumps with data collected using an uni-axial portable force plate sampled at 600 Hz and filtered using a 4th order Butterworth filter with a cut-off frequency of 50 Hz. Force-time data were subsequently analysed. The VJ variables, peak velocity, peak force, peak power, and jump height and landing force were measured. Officers randomly completed the VJ in both an unloaded condition (5.5 kg – fatigues and M4 weapon slung) and a tactically loaded condition (23.5 ± 2.8 kg; $24.5 \pm 3.4\%$ body mass) with all operational equipment. The VJ heights of all three jumps were averaged to provide a final VJ height for analysis.

Paired sample t-tests were used to evaluate differences between the tests in loaded and unloaded

¹ filip.kukic@gmail.com



conditions. Magnitude of differences was calculated according to Cohen's effect size. Pearson's correlations were conducted to investigate relationships between the unloaded and loaded condition for each variable. The significance level for all data was set at $p < .05$.

The results of the paired samples t-test revealed no statistical difference between the initial and third VJ height performed in the repeated VJ test, for either the unloaded ($p = .864$) or loaded ($p = .898$) conditions. There were significant differences ($p < .001$) between the unloaded and loaded conditions in VJ height (0.34 ± 0.02 m; 0.26 ± 0.02 m, respectively) and peak velocity (2.57 ± 0.07 m.s⁻¹; 2.26 ± 0.08 m.s⁻¹, respectively) with large effect sizes ($d = -1.73$ and -1.71 respectively). All measures, with the exception of landing force ($r = .46$, $p = .35$) were significantly and strongly correlated

Lower body power in SWAT Officers is reduced during load carriage. This can potentially lead to decreased tactical performance in critical tasks, such as seeking, or moving between, cover. Officers should train in both unloaded and loaded conditions to increase lower body power and mitigate landing impacts.

Keywords: law enforcement, fitness, training, specialists

INTRODUCTION

Specialist tactical police officers, such as those serving in Special Weapons And Tactics (SWAT) teams, are required to carry occupational loads while performing tasks that include warrant execution, engaging armed offenders, and hostage rescues (Irving, Orr, & Pope, 2019). The loads comprise specialist equipment and clothing required of SWAT police and increase the loads carried and worn from the 10 kg typical of general duties officers (Baran, Dulla, Orr, Dawes, & Pope, 2018), to around 20 kg (Carbone, Carlton, Stierli, & Orr, 2014), and even in excess of 40 kg (Pryor, Colburn, Crill, Hostler, & Suyama, 2012) when ballistic shields and breaching devices are included. While these loads are important for protecting, sustaining and enhancing the operational capabilities of tactical personnel (Orr, 2010; Son, Lee, & Tochihara, 2013), they have been found to negatively impact the performance of tactical personnel (Carlton & Orr, 2014; Dempsey, Handcock, & Rehrer, 2013) and lead to a variety of injuries (Orr, Pope, Johnston, & Coyle, 2014).

Leg power is an important attribute in police officers and is required to perform high-intensity, short-duration actions such as pursuing fleeing suspects, arresting uncooperative offenders, executing dynamic entries during search warrants, and lifting objects of substantial weight (Dawes et al., 2017; Shephard & Bonneau, 2002). Successful execution of these tasks requires officers to have adequate leg power (Orr, Dawes, Lockie, & Godeassi, 2019). Where the legs have been shown to express peak power at around one's body mass, when the body is loaded with more than 8% of body mass, peak power output has been shown to be reduced (Pazin, Berjan, Nedeljkovic, Markovic, & Jaric, 2013; Suzovic, Markovic, Pasic, & Jaric, 2013). Considering this, load carriage can decrease leg power and decrease occupational performance in tactical populations (Dempsey, Handcock, & Rehrer, 2014). Previous research on police load carriage has found that even light loads (8-10 kg) can reduce leg power as measured through a vertical jump (Dempsey et al., 2014; Taylor et al., 2016), short distance sprints (Lewinski, Dysterheft, Dicks, & Pettitt, 2015; Taylor et al., 2016) and agility / change of direction speed runs (De Maio et al., 2009; Martin & Nelson, 1985). In regard to occupational task performance, the weight of tactical equipment is believed to negatively impact an officer's ability to pursue and apprehend a suspect (Stubbs, David, Woods, & Beards, 2008). Since SWAT officers must perform occupational tasks with loads heavier than general duties law enforcement officers, they may be at greater risk



of experiencing performance decrements. These reductions in performance can potentially put SWAT officers at an increased risk of injury within the dangerous workplace environments in which they are exposed (Carlton & Orr, 2014; Dempsey et al., 2014). Consequently, improving both the health and skill related aspects of fitness is a primary a focus of police officer training (Cocke & Orr, 2015; Mala, Szivak, & Kraemer, 2015).

It is known that load carriage can negatively impact tactical personnel's ability to perform occupational duties, including mobility (Orr, Kukić, et al., 2019) and quick explosive movements (such as jumping) (Dempsey et al., 2014). What has not yet been further investigated is the impact of a full tactical load on the leg power of specialist police officers (e.g. SWAT officers). Therefore, the purpose of this study was to investigate the effects of the standard tactical load worn by SWAT police on their leg power performance.

METHODS

Participants

The participants were six active male officers of a state SWAT police unit (mean age = 34.0 ± 7.4 years, mean height = 184.2 ± 3.3 cm, mean body mass = 96.3 ± 6.4 kg, mean years of specialist experience = 6.0 ± 6.8 years) who volunteered to participate. Inclusion criteria for participation were a) members of the specialist unit, and b) over 18 years of age. The exclusion criterion for participation was any officer who had an injury at the time of data collection. Ethics approval for the study was obtained by Bond University Human Research Ethics Committee (RO1585).

Load conditions

The participants underwent testing in both unloaded and loaded conditions. The unloaded condition consisted of the officer dressed in police issued fatigues, boots, a primary weapon (M4 carbine assault rifle) and a secondary weapon (9 mm Glock pistol) (Carbone et al., 2014). The loaded condition consisted of the attire in the unloaded condition plus full standard tactical assault clothing and equipment (Carbone et al., 2014). This included body armour and a helmet but excluded other specialist equipment, such as respirators and breathing equipment, that would be task-dependent (Carbone et al., 2014). The mean mass of the unloaded condition was approximately 5.5 kg with slight variations due to weapon modifications and clothing sizing differences. The mean mass of the tactically loaded condition was 23.5 kg (± 2.8 kg) and ranged from 19.7 to 27.3 kg with variations due to weapon modifications, sizes of body armour and additional personal preference stores. As a percent of body mass, mean tactical load was 24.5% ($\pm 3.4\%$) and ranged from 18.9-27.3%.

Outcome measures

Leg power was measured using a repeated vertical jump test. Vertical jump data were collected using a uni-axial portable force plate (400 Series Performance Force Plate; Fitness Technology, Adelaide, Australia) which has been shown to have high reliability and validity in a variety of jumping and landing tasks measures (Walsh, Ford, Bangen, Myer, & Hewett, 2006). Data were sampled at 600 Hz and filtered using a 4th order Butterworth filter with a cut-off frequency of 50 Hz. Force-time data was subsequently analysed (Ballistic Measurement System; Fitness Technology, Adelaide, Australia). Vertical jump variables assessed included peak velocity, peak force, peak power, jump height and landing impact force.



The order in which the subjects performed this test (i.e. unloaded or loaded) was randomised by ballot lot draw. Officers were instructed to step on the force plate and when ready, perform three continuous vertical jumps as high as possible with hands maintained on their hips consecutively without pause. A repeated vertical jump test was used because the authors believed that it would be more applicable to the duties performed by the SWAT Police and has been shown to have good reliability for force outputs in a previous study (Cormack, Newton, McGuigan, & Doyle, 2008). In the current study, the repeated vertical jump was modified to only three repeated jumps due to the difficulty of remaining on the force plate while under a full tactical load. Vertical jump height was calculated using the software by measuring the amount of time the feet are not in contact with the plate. This was calculated for the initial jump and two rebound jumps performed by each officer. Officers were allowed two attempts with the best result recorded as their score. A rest of three minutes between the attempts and 10 minutes between the load conditions allowed for full recovery between attempts.

Statistical Analyses

Data were imported and statistically analysed using SPSS Statistics for Windows, Version 23.0 (IBM Corp. Armonk, New York, USA) and plotted in GraphPad Prism version 6.0 for Windows (Graph-Pad Software, San Diego, California, USA, www.graphpad.com). Paired sample t-tests were used to evaluate differences between the tests in loaded and unloaded conditions. The significance level for all data was set at $p < .05$. Trends of $p < .10$ were also noted due to the small sample size. The magnitude of differences was calculated according to Cohen's effect size (d) calculation, whereby the magnitudes were defined as small = 0.2, moderate = 0.5, large = 0.8 and very large = 1.3 (Sullivan & Feinn, 2012). Pearson's correlations were conducted to investigate relationships between load conditions (i.e. unloaded and loaded) for all variables and between first and third jumps.

RESULTS

All six participants completed each of the tests as previously described. Descriptive data and comparisons of the repeated vertical jump (averaged across the three repeated jumps) parameters in unloaded and loaded conditions are shown in Table 1. The average vertical jump peak velocity was significantly lower (-0.31 ± 0.04 m/s, $-8.48(5) = 2.57$, $p < .001$) in the loaded condition. Average vertical jump height was also significantly reduced (-0.08 ± 0.01 m, $-9.20(5) = 2.57$, $p < .001$) in the loaded condition. These negative effects of the load occurred for each participant (Figure 1a), with larger relative differences in jump height than jump peak velocity (Figure 1b).

Table 1. The influence of loading on average of repeated vertical jump performance.

Variables	Unloaded Mean $\pm$ SEM	Loaded Mean $\pm$ SEM	Difference Mean $\pm$ SEM
Vertical jump peak velocity (m/s)	2.57 ± 0.07	2.26 ± 0.08	$-0.31 \pm 0.04^{**}$
Vertical jump peak force (N)	2369.42 ± 114.20	2491.21 ± 74.07	121.79 ± 67.20
Vertical jump peak power (N/s)	4641.15 ± 239.97	4488.26 ± 276.86	-152.89 ± 93.00
Vertical jump height (m)	0.34 ± 0.02	0.26 ± 0.02	$-0.08 \pm 0.01^{**}$
Vertical jump landing force (N)	3169.53 ± 143.38	3180.38 ± 108.23	10.85 ± 133.71

****Significant at $p < .001$**



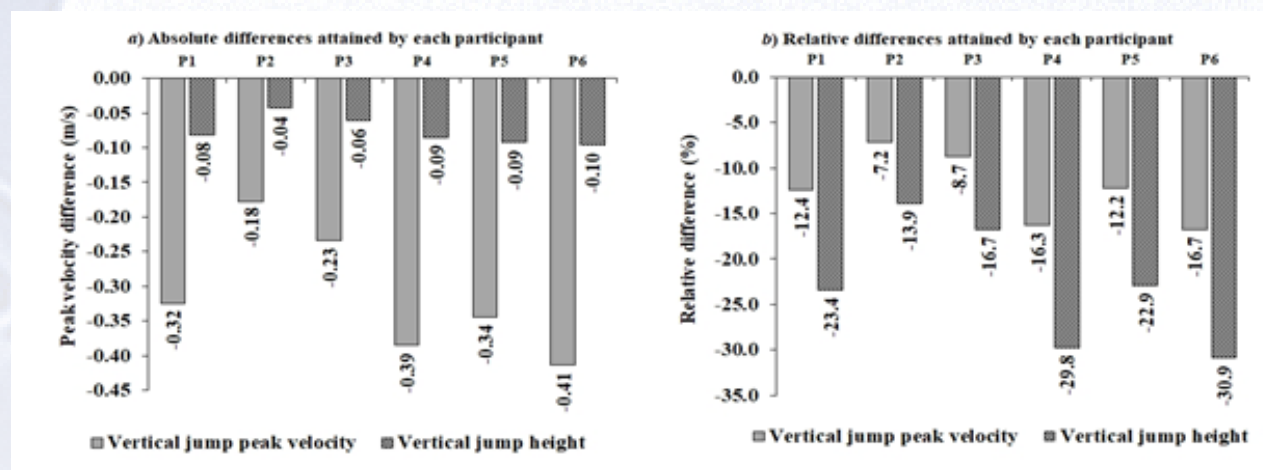


Figure 1. Absolute (a) and relative (b) differences in vertical peak velocity and vertical jump height for each participant.

Cohen's d and relative differences (%) between the unloaded and loaded condition in vertical jump peak velocity and vertical jump height are showed in Figure 2. The impact of the load was relatively greater on the vertical jump height than on the vertical jump peak velocity.

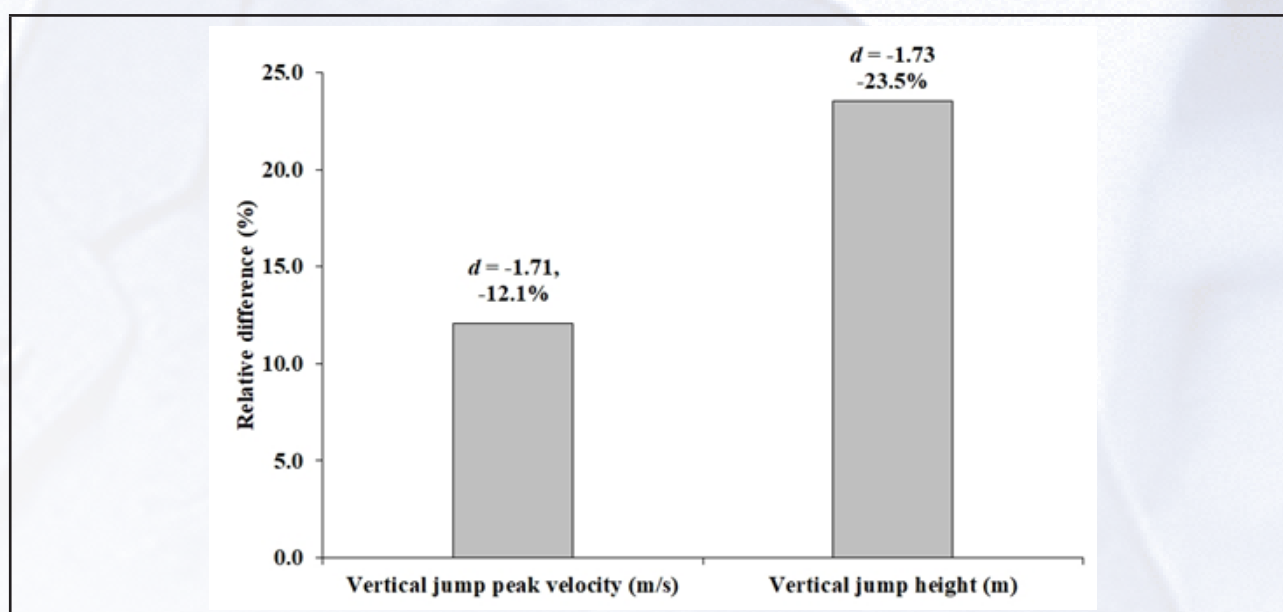


Figure 2. Cohen's effect size (d) and relative (%) difference between the unloaded and loaded conditions.

Significant strong correlations between unloaded and loaded performance of the repeated vertical jump were found as detailed in Table 2. However, no significant correlation was found between the unloaded and loaded impact forces for the vertical jump.

Table 2. Correlations between the unloaded and loaded performance of the repeated vertical jump.

Variables	<i>r</i> value	<i>p</i> value
Vertical jump peak velocity (m/s)	.90	.02
Vertical jump peak force (N)	.83	.04
Vertical jump peak power (N/s)	.95	.004
Vertical jump height (m)	.90	.02
Vertical jump landing force (N)	.46	.35

A two-tailed paired student's t-test revealed no statistical difference between the initial vertical jump height and the final third jump performed in the repeated vertical jump test, in both the unloaded ($+0.00 \pm 0.01$, $-0.18(5) = 2.57$, $p = .86$) and loaded (-0.00 ± 0.00 , $0.13(5) = 2.57$, $p = .90$) conditions. The jump height of the initial vertical jump under loaded conditions correlated significantly with the performance of the final third vertical jump ($r = 0.99$, $p < .001$). However no significant correlation was found in the unloaded condition between the first and third vertical jump heights ($r = 0.63$, $p = .18$).

DISCUSSION

The aim of this study was to investigate the effects of the standard tactical load worn by SWAT officers on their leg power using a repeated vertical jump. Significant differences were found between the unloaded and loaded conditions with these differences highlighted above in Table 1.

The average peak vertical jump velocity in the loaded condition was 12.2% lower than the unloaded condition. Additionally, the average jump height with load carriage decreased by 22.7% compared to the unloaded condition. These reductions in performance follow the previous finding by Dempsey et al. (2014) in which additional load carried (7.65 kg armour vest) decreased the jump height of police by 11.95%. Compared to the findings of Dempsey et al. (2014), a larger reduction in vertical jump performance was found in this study. This larger reduction can be attributed to the heavier loads used in this study (23.5 kg) for the loaded condition when compared to that of Dempsey et al. (2014). The change between the unloaded and loaded vertical jump peak force (2369.42 vs. 2491.21 N respectively, $p = 0.13$) and power (4641.15 vs. 4488.26 N/s respectively, $p = 0.16$) generated by the participants remained similar, suggesting that the muscle force produced was largely unchanged. However, since the total mass in the loaded condition was increased it follows that vertical jump height and velocity was reduced as the force exerted on the mass remained the same. Together, these findings further support previous research in which load carriage decreased tactical performance and put members of a SWAT unit at increased risk of injury (Carlton & Orr, 2014; Dawes et al., 2015; Dempsey et al., 2014). Load carriage is known to decrease carrier mobility and impact their ability to rapidly seek cover or accelerate in tactical situations (Carlton & Orr, 2014; Dempsey et al., 2013). Risk of injury increases with load carriage as additional loads can alter movement techniques, increase loads across the body and decrease mobility which increases occupational risk (Carlton & Orr, 2014; Dempsey et al., 2013; Orr et al., 2014).

The average landing impact force was not significantly different between loaded and unloaded conditions, suggesting that participants were able to effectively mitigate the impact of additional mass upon landing. However, this may be due in part to the reduced jump height achieved with the additional



load carried. Previous research has found that additional loading increases landing forces (13–19%, $p < .001$) when dropping from a fixed height (P. Dempsey et al., 2014). The results presented in this study suggest that when unfatigued, members of a SWAT unit were able to effectively manage the additional mass when landing from a jump with tactical load, an activity which may be performed in a tactical situation to clear an object or as an evasive manoeuvre (Dawes et al., 2015). However, if they were required to vault from an object or drop from a fixed height, Dempsey et al. (2014) has shown that landing forces would increase with additional load carriage.

Additionally, there were strong (Mukaka, 2012) significant correlations between the unloaded and loaded vertical jump performance for average peak velocity, peak force, peak power and peak height but not for the landing impact force. This suggests that the unloaded vertical jump performance relates to the loaded performance but not necessarily so for the landing ability of the police officer. Therefore, improving unloaded vertical jump performance is likely to translate into increased loaded vertical jump performance but not in landing capabilities in SWAT police. This is an important consideration for the selection of appropriate training loads and volumes across different training cycles, with a need to monitor the total exposure and adaptation (positive and negative) to load carriage. Repetitive overloading due to load carriage is known to be linked to an increased risk of injuries in tactical populations, particularly in soldiers (Orr et al., 2014). However, vertical jump impact force (i.e., landing capabilities) did not correlate between the two loading conditions, suggesting that strength and conditioning as well as tactical training should be carefully crafted to include training in both loading conditions.

No statistical difference was found between the initial vertical jump height and final third vertical jump height achieved during either the unloaded and loaded condition. The results suggest that while not fatigued, the performance of a short series of repeated jumps remains unaffected by load. Also, a correlation was found between the initial vertical jump height and third final vertical jump height in the loaded condition, but not in the unloaded condition. This is likely due to the increased variation in the raw data for jumps in an unloaded state, which has been previously noted in research by Cormack et al. (2008).

LIMITATIONS

Limitations of this study were mostly due to the low sample size and consequential natural variations in the data which made it more difficult to observe statistically relevant phenomenon. Additionally, since anthropometric data on the individual participants was not available, we were not able to factor in any potential confounding effects of body mass, body composition, age and height on leg power and strength performances.

CONCLUSION

Specialist police personnel, such as those serving on a SWAT team, are often required to carry substantial loads during their occupational duties. These loads can impact their leg power performance which is an important physical requirement for tactical task performance. This study suggests that the performance of leg power in SWAT police is reduced during load carriage. This can potentially lead to decreased tactical performance and increased risk of injury. Additionally, unloaded performance



of leg power relates to loaded performance. Therefore, training which increases unloaded leg power is likely to carry over directly into tactically loaded performance. However, vertical jump landing force (i.e., landing capabilities) did not correlate between the two loading conditions, suggesting that strength and conditioning as well as tactical training should be carefully crafted to include training in both loading conditions. This is of importance as good capability in landing, deceleration and stopping while carrying loads may reduce the risk of injury. Taken together, these findings have implications in the understanding of tactical performance with load carriage. To further elucidate the impact of load carriage on leg power, it would be beneficial to conduct future studies with simulated tactical situations to see the effect of fatigue with load carriage.

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