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Load Carriage: Reductions in soldier task performance and the risks posed

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ABSTRACT

Australian military personnel are required to carry load as part of their occupation. Research suggests that these loads are increasing with reports that Australian soldiers have carried mean loads of around 30 kg in the World Wars, 36 kg in Vietnam and 48 kg on operations over the last two decades. While acknowledged as causing soldier injuries, the impacts of load carriage on task performance are often forgotten.

As soldier loads increase, the mobility, lethality (marksmanship and grenade throw ability), general task and attention-to-task abilities of the carrier have been found to decrease. Decreases in soldier mobility have altered the battle tactics of armies and increased casualties in previous and current conflicts. Through reducing a soldier's ability to engage and suppress an enemy, decreases in lethality can be postulated to reduce the potential for mission success and increase the risk of battle casualties during an engagement. Considered concurrently, reductions in both mobility and lethality reduce the effectiveness of the basic military combat manoeuvre, being fire-and-movement. This in turn further augments the risk of battle casualties. Reductions in attention-to-task (most notably visual cues) can impair a soldier's ability to detect an improvised explosive device on a patrol or a hidden weapon at a checkpoint. Overall, these reductions in task performance highlight the potential force degeneration risk afforded by current load carriage practices.

This paper will commence with a brief historical review of Australian soldier load carriage practices before discussing the impacts of these loads on soldier task performance. The possible consequences of these impacts will be reviewed and potential force degeneration effects examined. Discussed strategies will focus on improving military conditioning and training practices to mitigate these impacts.

1. The Australian Army Load Carriage Context

1.1 Previous conflicts (1914-1999)

The loads soldiers are required to carry are increasing [1, 2]. At Gallipoli, Australian soldiers were thought to carry a mean load of 33.5 kg [3] with slightly lighter loads of between 27 kg and 28.5 kg carried when assaulting Mont St Quentin, [4]. Little

changed leading into the Second World War with Australian soldiers reportedly carrying between 22 and 32 kg into the battles at Bardia and El Alamein in the North African desert [5, 6] and 20.5 to 41 kg in the Pacific [7-10].

During the Vietnam War, loads were generally heavier, weighing between 32 to 36.5 kg [11] and, in some cases, more. Several members from the 8th Battalion, Royal Australian Regiment (RAR), weighed their packs and found themselves carrying loads of between 36.5 kg and 54 kg [12]. These loads were similar for the soldiers of the 4th Battalion, RAR, who likewise carried loads of between 30 kg and 40 kg (rifleman) and up to 47.5 to 56 kg (radio operators) [8, 13, 14]. In more recent operations in East Timor, Australian soldiers on Operation CITADEL (2002–2003) carried loads in excess of 45 kg, with gunners and signallers carrying loads in excess of 50 kg [15]. These loads were considered to affect their ability to chase fleeing militia [16].

1.2 Current Conflicts

1.2.1 Weight of Load Carried on Operational Tasks

Survey data captured as part of a cross sectional study of Australian Regular Army (ARA) load carriage practices provided a total of 301 responses relating to operational load carriage [17]. The data provided by respondents spanned more than a decade of operational duties.

Based on respondent data, ARA soldiers carried an average load (dressed in either Patrol Order or Marching Order) of 48 kg over the last decade while on operations. This load represented 56% of respondents' mean body weight. Patrol order alone equated to an average load of 28 kg, with Marching Order loads averaging 57 kg.

The load weights represented in the survey were consistent with other sources used to triangulate data. For example, respondents claimed that loads carried between 2002 and 2003, a period coinciding with the ADF OPERATION CITADEL deployment, averaged 46 kg. These self-reported loads support Paulson's [15] statement that Australian soldiers carried loads in excess of 45 kg during this operation. Similarly, McMahon [18] claimed that while he was on military operations in Afghanistan as a member of the Engineer corps, a fellow member carried a Marching Order load of approximately 75 kg. Marching Order data presented in the survey, which corresponds to the time period and corps, indicated loads which ranged from 69 kg to 86 kg for this population.

A review of loads by respondent's corps identified some significant differences in load weights between corps. The average reported absolute Marching Order loads carried by Infantry corps (61 kg), Armoured corps (61 kg), Engineer corps (59 kg) and Artillery corps personnel (58 kg,) were heavier than loads carried by Signals corps (54 kg) and grouped responses from 'other' corps (42 kg). These differences in load weights remained when female data were removed from the Signals and grouped 'other' corps data.

Female soldiers (11% of responses), regardless of dress, reported carrying significantly lighter average *absolute* loads (26 kg) during military operations than their male counterparts (39 kg). While differences were found when the loads were expressed in *relative* terms (average female *relative* load of 43% body weight; average male *relative* load of 47% body weight) the differences were not statistically significant. The key reported difference in carried loads between male and female soldiers during military operations was the significantly heavier *absolute* loads carried by male soldiers in their webbing.

An analysis of the operational loads carried by the lightest 20% of male respondents and the heaviest 20% of male respondents

(n=18 per group) yielded no significant differences in the *absolute* loads carried between the lighter group (35 kg,) and the heavier group (35 kg). Conversely, when *relative* loads were analysed, differences between the lightest 20% and the heaviest 20% of male respondents approached significance with the lightest respondents reportedly carrying loads that represented 49% of their body weight, while loads representing 36% of body weight were carried by the heaviest male respondents.

1.2.2 Tasks performed while carrying load on operations.

When surveyed, ARA soldiers identified foot patrols as the most dominant task type when carrying loads on operations (50% of tasks) [17]. This was followed by mounted patrols (25% of tasks), administration (17%) and lastly static patrols or standing at post (8%). When assessed over two decades, research suggests that the dominance of patrolling on foot or walking might be reducing (from 67% down to 45% of total tasks), with mounted patrols increasing (from 9% up to 29% of total tasks).

This increase in mounted patrols may be due to several factors, including changes in operational theatres, equipment availability, and operational requirements. As an example of the impact of a change in operational theatres, certain areas on the outskirts of Kabul, Afghanistan, are only traversable by a mounted patrol as they are claimed to be associated with a high risk of harm from mines [19]. Changes in equipment availability to enable a shift from unmounted to mounted tasks have also contributed. For example, the ADF Infantry Mobility Vehicle, or 'Bushmaster' was introduced mid-2004 [20]. Moreover, limited availability of air mobility assets increases the needed for land mobility and may have led to an increased need for vehicle mounted movement of soldiers [21, 22]. Changes in operational requirements might also have contributed to the reported increase in the ratio of mounted to unmounted load carriage tasks. For example, in Afghanistan increased use of combined mounted and foot patrols as opposed to foot patrolling only has been used to move troops through mined areas and to provide protection from improvised explosive devices [19]. These factors may act in isolation or be interrelated. For example, the increased need for mounted patrols may be leading to the purchase of additional mobility vehicles, allowing for an increase in combined mounted and dismounted operations.

2. Impacts of Load Carriage on Soldier Performance

Excessive loads carried by soldiers have altered battle tactics and led to soldier deaths in previous conflicts [23]. The U.S. Field Manual 21-18 (FM 21-18) entitled *'Foot Marches'* states that the primary consideration is not how much soldiers can carry, but how much they can carry without impairing combat performance [24]. With fatigue defined as *'a state of weariness caused by physical and/or mental exertion'* [25] and load carriage found to increase physical exertion, load carriage can be expected to contribute to soldier fatigue and consequently affect soldier combat performance in functional areas including mobility, lethality, ability to perform general tasks, and even cognition.

2.1 Impacts of Load Carriage on Soldier Mobility

As load weight increases, the time taken for soldiers to march a given distance can be expected to increase [26-29]. Furthermore, as the weight of the carried load increases, the associated decrease in mobility may be more pronounced. In the Great War, heavy loading of the foot soldier reduced the

marching ability of the average soldier and was claimed to have altered the tactics of war [30]. The Battles of Cambrai and Amiens provide examples in which forward movement, limited predominantly by physical exertion, was reduced to 9 km to 12 km per day [30]. In a more recent conflict, the loads carried by Australian soldiers in East Timor were thought to reduce their ability to chase Militia fleeing into the bush [16].

Apart from marching, increases in load weight increase the time a soldier takes to traverse obstacles [28, 31-34]. For some soldiers, increases in load weight may even reduce their ability to successfully negotiate an obstacle. Finally, increases in load weight increase the risk to the soldier of tripping when moving across debris (like that found in battle-damaged buildings or areas) [31-33]. This in turn increases their risk of sustaining an injury through slips, trips and falls.

2.2 Impacts of Load Carriage on Soldier Lethality

In most [27, 35-37] but not all studies [38], increases in load weight carried have been associated with decreases in soldier marksmanship performance. Similar results have been found with grenade throw performance, with three [29, 35, 36] of four [27] identified studies observing a negative association between load carriage tasks and grenade throw performance. On this basis, increases in the load weight carried by soldiers can be expected to negatively impact on their lethality through potentially decreasing marksmanship and grenade throw ability.

2.3 Impacts of Load Carriage on Soldier Administration Task Performance

Load carriage can negatively affect the soldier's ability to perform general tasks both during load carriage and for a period immediately following it [39-41]. These negative impacts have been observed with loads as light as 10 kg body armour when performing simulated work [41]. Potential causes of this reduction in task performance may be impairments of neuromuscular functioning (force production through voluntary contractions) [39], decreases in physical work capacity (combined measures of oxygen uptake and physical strength) and fatigue [40, 41].

2.4 Impacts of Load Carriage on Soldier Attention-to-Task

Load carriage may negatively affect the alertness, vigilance and executive processing of mental operations (situational awareness) of soldiers [26, 42, 43]. Not only do heavier loads have a more significant impact on alertness than lighter loads [26], but vigilance to randomly presented stimuli (auditory, tactile and visual) have been found to decline when heavier loads are carried [43]. This decline in vigilance was significantly greater when responding to tactile and visual stimuli than auditory stimuli and poorest while walking around obstacles. Furthermore, both the speed and accuracy of decision making may be affected when soldiers carry loads, with a degradation of mental operations involved in executive processing (i.e. performing goal directed actions in an environment featuring complex stimuli) observed when military personnel stood loaded with 30% of their body weight in a military backpack [42].

2.5 Perceived Impacts of Load Carriage on Soldier Task Performance

While empirical research has identified the impacts of load carriage on soldier task performance, another point of consideration is the soldier's perceptions of the impact of load carriage on their task performance. This perception can be more telling than

measured impacts alone. For example, if a soldier considers the loads they carry to have a greater impact on their marksmanship than measured indicators suggest, a soldier may expend more ammunition or carry more ammunition (and hence load weight) in order to mitigate their perceived poorer marksmanship. Conversely, if a soldier considers that the loads they carry do not impact on their lethality, they may be more willing to engage an enemy, overly confident that their accuracy will not lead to collateral incidents.

When asked to rate their perceptions of the impacts of the loads they carried on operations on their ability to perform military tasks (from -2 notable impact to +2 notable improvement), Australian Army soldiers generally considered load carriage to negatively impact on all five criteria (mobility, marksmanship, grenade throw performance, administration, and attention-to-task)[17]. As shown in Figure 1, these soldiers considered mobility to be the most notably impacted by their loads (mean rating of -1.24). Interestingly, while still noted as reduced performance, attention-to-task was considered to have been the least negatively impacted by load carriage.

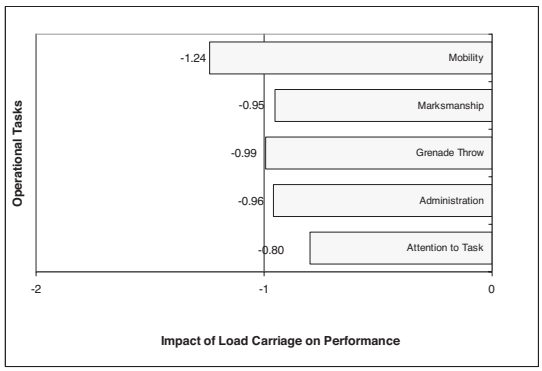

Figure 1: ARA Soldier perceptions on the impacts of operational loads carried and performance

3. Potential Consequences of these Impacts of Load Carriage on Soldier Performance

Load carriage events can impair soldier military task performance. These impairments on soldier task performance have in turn downstream impacts for the military, most notably force degeneration and mission success.

Potential reductions in mobility, lethality and attention-to-tasks can increase the vulnerability of soldiers to combat wounds and even fatalities. Reductions in mobility while carrying loads may increase a soldier's exposure to enemy fire, with the soldier moving more slowly between areas of protective cover. The findings of Pandorf et al.[28] illustrate this point: the time taken to complete a section of an obstacle course with four step-overs increased from a mean of 5.4 seconds to a mean of 6.8 seconds as loads increased from 14 to 27 kg. If a soldier was exposed to enemy fire from an AK-47 assault rifle on full automatic fire (Based on a cyclic rate of ammunition fire of 600 bullets per minute [44]) this delay would expose the soldier to an additional 14 bullets per engaging enemy rifle when negotiating this single obstacle.

A means of reducing the moving soldier's exposure to enemy fire is accurate application of suppressive force onto the position of the enemy by fellow soldiers. However, with the reduction in lethality skills (like marksmanship and grenade throwing ability) associated with soldier load carriage, protective fire for the moving soldier, who in turn is more exposed due to reduced mobility, may be reduced and the enemy may be more able to apply effective weapon fire towards the exposed soldier.

Finally, impairments in attention-to-task associated with load carriage may reduce

the soldier's concentration and increase their risk of injury or mortality. On operational duties, for example, impaired concentration could reduce a soldier's ability to identify signs of improvised explosive devices (IEDs) when on patrol. The potential effect on military force degeneration of impaired attention to task (like scanning for IEDs) associated with load carriage tasks is made more poignant given that IEDs were associated with 72% of Australian soldier combat injuries (18 of 25 affected personnel) so far in 2012, and 42% of Australian soldier mortalities (14 of 33 deaths) during the Afghanistan conflict [45]. This concern may be even more poignant when considering that Australian Army soldiers perceive attention-to-task as being the least negatively-impacted ability.

Impaired performance associated with soldier load carriage tasks can affect the ability of soldiers to complete tasks associated with mission success. For example, the role of the Australian Infantry is to *'seek out and close with the enemy, to kill or capture him, to seize and to hold ground, to repel attack, by day or by night, regardless of season, weather or terrain*' [46]. Impaired performance associated with the loads carried by soldiers could limit their ability to close with the enemy, as was the case described by Breen [16], where Australian soldiers in East Timor could not chase fleeing militia due to the heavy loads they were carrying. Reduced lethality would affect the ability to engage the enemy, to hold ground and to repel attack.

4. Military Physical Conditioning and Training

Improved equipment integration and reducing the physical load carried provide two means of potentially limiting the impact of load carriage on the soldier [47]. These two methods however require notable investment. While these methods are important to a long-term load carriage solution, military physical conditioning and specifically focused additional military training can be used to optimise military task performance during load carriage events.

4.1 Military Physical Conditioning Programs

The need to condition military personnel to carry loads can be traced to antiquity [2]. As an effective means of improving load carriage task performance and helping prevent load carriage injuries [1, 48], physical conditioning forms a vital part of force sustainment. This is only the case, however, if the training is conducted appropriately.

Current research suggests that optimal frequency for load carriage conditioning is one load carriage session, evenly spaced, every two to four weeks [1, 49, 50]. The intensity of the training sessions needs to be sufficient to elicit the desired training response and should progress to carrying loads similar to those required for military operational tasks and carrying them in similar contexts (with regard to speed and terrain, for example). Furthermore, the durations of the load carriage sessions need to increase to meet with occupational requirements. As a general rule, however, increases in intensity and duration should not occur concurrently. While load carriage specific conditioning sessions are vital to load carriage performance, supplementary training that may further enhance load carriage performance or aid in injury reduction is of value. These supplementary sessions should include both muscle conditioning and aerobic training sessions [51-54].

In order to facilitate these conditioning requirements, a periodised training program is needed. Periodised training programs manipulate training variables, such as

intensity and volume, to ensure optimal performance is achieved [55]. In addition, the use of a wave-like periodised model will allow for the inclusion of recovery periods or 'orthopaedic' holidays [56] and as such aid in injury prevention.

Considering the potential for a 'law of diminishing returns' to exist, where fitness gains decrease with the amount of exposure (in this case training frequency) [57] as well as a possible 'genetic ceiling [58]', or a finite point to the carrier's physical ability, there is ultimately a maximum amount that an individual can be conditioned to carry [59]. As such, even though an individual who is well conditioned may be able to carry a heavier load, there will still be a load threshold above which they will be overloaded [60].

4.2 Supplementary Training for Load Carriage

Apart from direct methods, load carriage conditioning can also be achieved indirectly. In this paper, indirect methods relate to load carriage conditioning achieved incidentally to other objectives. Two examples, discussed below, are the performance of in-barracks duties and lethality training while wearing load carriage ensemble.

4.2.1 Load carriage in-barracks

A means of increasing load carriage exposure is through employing load carriage protocols during the performance of everyday tasks while in-barracks. For example, every Monday of the week while in-barracks, all soldiers may be required to wear 'patrol order' or 'fighting order' (webbing and patrol pack) as their 'dress of the day'. This indirect means of conditioning allows for exposure to a load carriage stimulus without further impacting on current work hours. Furthermore, greater exposure to wearing a load carriage ensemble may increase the soldier's ability to perform military tasks while wearing load [61].

4.2.2 Lethality Training

With load carriage observed to impact on soldier lethality and soldiers themselves considering load carriage to reduce their lethality skills, lethality training, like range shooting, should be conducted wearing loads that progressively increase to meet with operational requirements. In the Australian Regular Army, soldiers are required to complete bi-annual shooting requirements as part of their readiness [62]. Often these shooting assessments are conducted on pristine ranges or in simulator facilities with the soldier wearing patrol order, which is often empty except for the weapon magazines required of the shoot. Wearing operational loads when required to conduct range shooting and other lethality training (like a grenade throw) will provide the soldier with direct feedback on the impact of the loads they are required to carry on operations and their actual shooting performance.

It should be noted that in-barracks training and lethality training are but two suggested means of providing supplementary training for load carriage optimisation. Within individual units other potential means and methods should be explored. Any supplementary training must however be cognisant of the overall load carriage conditioning program and carefully integrated into the unit's training program if these methods are to optimise load carriage rather than become a source of injury risk.

5. Conclusion and Recommendations

Load carriage has led to the deaths of military personnel in previous conflicts. Considering this, to provide for sustainment and protection, Australian soldiers are still required to carry loads as part of their

occupation. Carrying these loads can have countervailing effects on both the soldier through reducing their ability to perform key tasks, and the Australian Army, through potential reductions in force sustainment and mission success.

Recommendations to help mitigate these impacts include: i) the use of a structured military physical conditioning program focussing on load carriage and ii) the use of additional training methods like the performance of in-barracks duties and lethality training while wearing load carriage ensemble.

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