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# RESISTANCE EXERCISE CONSIDERATIONS FOR LOAD CARRIAGE

## INTRODUCTION

Load carriage (LC) is one of the most physically taxing demands encountered by tactical professionals and this demand continues to grow. In the past three decades of international conflicts alone, load requirements have increased by more than 50% (20). Current North Atlantic Treaty Organization (NATO) guidelines for military LC recommend loads of up to 45% of an individual's bodyweight in a deployed setting, and United States Army guidelines recommend loads ranging from 80 – 125 lb depending on operational factors (17). However, a landmark analysis of combat operations in Afghanistan demonstrated that external loads frequently exceeded doctrinal recommendations (2). Even more concerning, infantrymen often struggled with LC-related tasks when factoring in operational considerations such as extended mission duration, rugged terrain, higher altitudes, and the requirement to carry extra water in summer desert temperatures (2).

To date, LC is the largest contributor to musculoskeletal injury (MSKI) even in deployed environments, exceeding injuries sustained due to enemy contact (16). Importantly, repeated exposure to LC tasks over the course of a tactical career not only exacerbates MSKI risk, but once injury is present, the risk of reinjury increases (15,20). For these reasons, optimal physical preparation is of paramount importance. For the tactical professional perhaps more than any other population, optimal resistance exercise (RE) strategies must be carefully designed and implemented in order to elicit desired physiological adaptations and performance outcomes. Common LC tasks, such as offensive and defense infantry maneuvers, are composed of a heavy anaerobic component; thus, prior research has described the demands faced by the tactical professional as the "anaerobic battlefield" (11,13). With this definition in mind, to best prepare for LC, RE must address three main areas: strength and power development, work tolerance and fatigue resistance, and injury risk mitigation via dynamic trunk stability.

## STRENGTH AND POWER DEVELOPMENT

To best understand why heavy loading matters in the context of training for LC, one must first consider the importance of specificity. The law of specificity dictates that physiological adaptations are dependent upon the specific stimuli placed on the body, in other words, training must be specific to LC demands to best prepare individuals for LC-related occupational tasks. To achieve optimal LC capability across the full range of loading intensities commonly encountered, RE strategies must incorporate loads that mimic those demands, both in terms of absolute load as well as loading intensities relative to the individual's own body mass. Currently, typical loads carried range from 40 – 60 kg, and in some cases, may exceed 70 kg or more (20). Such extreme loads may equal or exceed an individual's own body mass (2,20). It is critical to recognize that lean body mass (LBM) as well as strength and power capabilities ultimately determine an individual's ability to tolerate such loads without significant physical detriment, and importantly, may mean the difference between mission success and failure.

When evaluating LC tasks within the context of the tactical profession, one must consider that the operational environment itself presents significant stressors such as harsh terrain, elevation, and temperature extremes, or psychological stress. To prepare individuals to perform occupational tasks effectively under these conditions, while also contending with the additional stress represented by external load, developing strength and power capabilities is critical. First and foremost, research has shown that optimal LC is directly related to strength and power capability, particularly with regards to trunk musculature as the seat of power production (8,12,21). Similar observations have been seen in an athletic context (1,21). Second, the extent of physiological stress that a given load represents is directly proportional to the individual's own body mass (7,20). Therefore, it is advantageous for the tactical professional to fully develop strength and power capabilities as well as LBM. Research has shown that high-intensity, high-volume RE protocols are most effective at eliciting anabolic hormonal responses and activating large, high-threshold motors units, which ultimately results in favorable adaptations in terms of muscle hypertrophy, force production, and power development (3,10). As an additional benefit, high-intensity, high-volume RE also impacts skeletal muscle repair and remodeling processes as well as connective tissue and bone strength, thereby contributing to injury prevention and general physical health (4,11).

## WORK TOLERANCE AND FATIGUE RESISTANCE

LC tasks vary not only in magnitude of load, but also in distances covered. One of the most common LC tasks, conducting dismounted patrols, may involve relatively short distances of a few kilometers to longer distances of up to 15 – 20 km in rarer cases, with distances being mission-dependent (2). Furthermore, within the context of operational scenarios, LC tasks seldom occur without additional stressors, such as mild to moderate caloric deficit and dehydration, not to mention potential enemy contact (2). If an individual has poorly developed strength and power capabilities under these circumstances, fatigue will set in more quickly. Additionally, strength and power are typically among the first qualities to deteriorate with detraining or with the addition of external stressors; thus, efforts to maximize these capabilities prior to exposure to the operational environment can be tremendously beneficial in maintenance of LC capability and injury prevention

(4,11). For these reasons, RE should not only address strength and power development but must also address work tolerance and fatigue resistance (i.e., building the capacity to tolerate varying loads across a range of distances). Although direct, task-specific LC training is particularly beneficial with regards to building work tolerance, RE offers a complementary training alternative.

For tactical professionals, moderate loading intensities certainly have their place in a well-designed RE training plan, given the requirement for LC across variable distances, in addition to the high risk of MSKI associated with chronic external LC. Strength and power capabilities must still predominate, as to reiterate, these deteriorate quickly with detraining and fatigue. However, other training qualities, such as local muscular endurance and fatigue resistance, must not be neglected. First and foremost, moderate RE loading intensities in the hypertrophy range are typically recommended for building local muscle endurance. Secondly, training approaches which incorporate a combination of shorter rest periods, circuits, and supersets can be effective in improving fatigue resistance and offer the benefit of time-efficiency. Finally, adding higher volume RE training sessions within a given training phase can be a beneficial means of building tolerance to increased workloads. Thus, RE strategies require a balance between anaerobic emphasis for optimal strength and power development and building work tolerance, or more specifically, local muscle endurance. Although beyond the scope of this article, aerobic capacity must also be developed, and is best addressed in a concurrent approach that does not compromise anaerobic training priorities (9).

## DYNAMIC TRUNK STABILITY AND INJURY PREVENTION

Posterior LC is known to result in biomechanical and kinematic changes, such as increased forward trunk lean, increased hip flexion, and forward positioning of the head and neck as a result of the body attempting to stabilize under load (6,18). While these changes in and of themselves are concerning and present risk for injury, the addition of external load exacerbates this risk and contributes to increased incidence of back pain (6,14). Furthermore, because the magnitude of load relative to the size of the individual determines the extent of physical demand, smaller individuals may be at greater risk of injury (1). Therefore, they can benefit greatly from building LBM to better tolerate heavy external loads. More importantly, LC is associated with MSKI incidence and the cumulative stress of LC-tasks on the lower extremities can lead to increased injury risk over the course of a service career (18). For these reasons, not only is optimal RE intensity a key consideration in building strength and power capabilities and increasing work tolerance, it is also critical in trunk stability and injury prevention.

Trunk stability exercise is traditionally thought of as isolated trunk exercises, such as planks or side bridges (19). While these exercises certainly are valuable, particularly as rehabilitative measures once pain or injury is present, trunk stability can also be trained through traditional RE across a range of loading conditions. For athletes, increased trunk stability provides the necessary foundation for development of optimal force and power production capabilities (21). Within the tactical context, optimal LC performance is also associated with well-developed strength and power capabilities, and LC has been shown to negatively affect power and agility performances (7). Thus, for the tactical professional, ability to maintain posture under dynamic external loading conditions may be one of the most important factors in LC performance and injury prevention. Willardson described trunk stability as "a dynamic concept that continually changes to meet postural adjustments or external loads accepted by the body," (21). Thus, any physical activity, such as RE which taxes stability of the trunk musculature under load can be considered a trunk stability exercise. To this end, a recent survey of strength and conditioning professionals supported the use of traditional RE, such as squats, Olympic lifts, and farmer's walks to develop dynamic athletic performance and trunk stability (1). Given the varying LC requirements encountered in the tactical professions, training dynamic movements across a full range of loading intensities has the added benefit of targeting improvements in dynamic trunk stability and thereby potentially reducing the risk of injury.

## PRACTICAL APPLICATIONS

Given the typical mission constraints faced by tactical professionals, arguably one of the most effective means of addressing multiple training priorities is the non-linear periodized approach, wherein training priorities are addressed within a given training phase in an undulating fashion (8). Such an approach has been well described in the literature (11,13). Important to the tactical professional, it also has the unique benefit of flexibility, which accommodates changing mission requirements, varying levels of readiness to train, and often limited training time available. Although other training approaches can be employed and can be effective, time-efficiency and adherence are often the most critical factors for tactical professionals. Furthermore, the non-linear approach allows for different training priorities to be addressed simultaneously, without the potential for a given training quality to deteriorate when not emphasized during a specific training phase, as can occur with traditional linear training approaches. Prior research has described strategies for incorporation of direct, task-specific LC exercise within a training plan and these should not be ignored (5,13). However, RE emphasizing strength and power capabilities, work tolerance, and dynamic trunk stability as described in this paper are complementary to traditional LC training and can be valuable components of an overall physical training plan (13). To summarize, RE performed at higher loading intensities results in the greatest anabolic hormonal stimulus, activation of higher threshold motor units, and the greatest translation of forces onto associated muscle, connective tissue, and bone. Meanwhile, the combination of moderate loads with shorter rest periods is an effective means to improve work tolerance and fatigue resistance, while the use of traditional RE across a range of loading intensities can greatly improve dynamic trunk stability.

Regardless of the specific training approach used, optimal RE strategies for LC should address the following:

- Implement RE loading strategies that address the full range of LC intensities encountered as part of occupational tasks.
- While direct, task-specific LC is important, physical training should also incorporate traditional RE as it has tremendous carryover to LC task performance.
- In addition to strength and power development, build work tolerance across varying RE loading intensities by manipulating volume, intensity, and rest periods.
- Train load under dynamic conditions to build trunk stability and enhance injury prevention.

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