ISSN: 2469-5718

Zimmermann and Lever. Int J Sports Exerc Med 2022, 8:214
DOI: 10.23937/2469-5718/1510214
Volume 8 | Issue 1
Open Access

International Journal of
Sports and Exercise Medicine

RESEARCH ARTICLE

Speed Marching in Military Boots: The Walk-To-Run Transition Speed and Vertical Ground Reaction Forces

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Abstract

Background: Speed marching is the term for moving on foot, in which service members alternate marching and running to cover a certain distance in limited time. The standard load for speed marching is 25 kilograms, this includes a backpack, a tactical vest and rifle. When increasing walking speed, a person will switch from walking to running at a certain speed, this is called walk-to-run transition. The walk-to-run transition speed for marching in military boots, with or without a rifle, is unknown. Marching and running are the source of many overuse injuries, the accumulation of impact forces plays a causal role. Research into alleviating the impact forces of military tasks, such as speed marching, is desirable.

Research questions:

1. What is the walk-to-run transition speed for marching in military boots, with standard 25 kg load, including a (practice) rifle?

2. What are the vertical ground reaction forces of marching and running at the speed of the walk-to-run transition?

Methods: A one-time series of measurements on an instrumented treadmill, in a running laboratory, on twelve healthy military service members.

Results: The walk-to-run transition speed averaged 7.4 km/h (SD 0.5 km/h). At 7.4 km/h, the maximum vertical ground reaction forces on the heel were less in running than in marching. The forces on the midfoot and forefoot were similar.

Conclusion: The walk-to-run transition speed, measured in 12 healthy and experienced military service members during speed marching in boots, with 25 kg standard load and a (practice) rifle, is 7.4 km/h (SD 0.5 km/h). At the speed of walk-to-run transition, vertical ground reaction forces were lower in running than in marching in this particular population and activity.

Recommendation: Switching from marching to running at a speed below the self-selected walk-to-run transition speed may reduce vertical ground reaction forces when marching with load in boots. Further research into the optimal transition speed from marching to running in military boots is warranted.

Keywords

Marching, Walk-to-run transition, Overuse injuries, Military, Occupational

Abbreviations

cm: centimeters; kg: kilogram; km/h: kilometers per hour; SD: Standard Deviation; vGRF: vertical Ground Reaction Forces

Introduction

Marching is a task that is inseparable from the military profession. Speed marching, sometimes called 'rapid marching', is a variant of marching. In a speed march, the aim is for a group of service members to bridge a distance on foot as quickly as possible and then carry out a (combat) action at the destination. Marching and speed marching are a standard part of basic and advanced military training. Speed marching is seen as

Citation: Zimmermann WO, Lever EM (2022) Speed Marching in Military Boots: The Walk-To-Run Transition Speed and Vertical Ground Reaction Forces. Int J Sports Exerc Med 8:214. doi.org/10.23937/2469-5718/1510214

Accepted: January 22, 2022; **Published:** January 24, 2022

a discipline that is suitable for training the physical and mental resilience of soldiers.

Usually, the performance of speed marching is as follows: alternating one minute of marching at a speed of 6 to 7 km/h, then two minutes of running at a speed of 8 to 9 km/h. There is also a variant, where one minute of marching and one minute of running are alternated. To keep the group together during the speed march, marching and running speeds are chosen that most participants can maintain. The distance to be covered for a speed march can vary from 3 to 15 kilometers. The standard load during training is about 25 kilograms, which includes a tactical vest and weapon (rifle). Military boots are generally worn during marching and speed marching.

Speed marching can lead to overuse injuries, especially of the lower extremities. The risk of an overuse injury in marching is greater than in running. The relative risk per distance traveled (kilometers) is approximately 1.8 (95% CI 1.38-2.37) [1]. The injury risk of speed marching, as described above, is not known. Most overuse injuries in the armed forces occur during initial training, in young soldiers, and are mainly localized to the knee and leg [2].

In military health care in The Netherlands much attention is paid to the prevention and treatment of overuse injuries that can arise from running and marching. For example, primary care (the health centers at the barracks), secondary care (the Central Military Hospital), and tertiary care (the Military Rehabilitation Center) have all undertaken investigations in recent years to optimize the treatment of soldiers with overuse injuries of the legs [3].

The Department of Military Sports Medicine of the Royal Netherlands Army is an institute for secondary care and a research institute. An important task is to promote the prevention and treatment of overuse injuries of military personnel. In recent years, research has been conducted on running in sports shoes and military boots. Gait retraining, the teaching of a running technique with less impact forces (vertical ground reaction forces), has become an integral part of the treatment of soldiers with overuse injuries of the lower extremity [4]. A study on the vertical ground reaction forces that occur during marching in boots at a speed of 5 km/h was also completed [5]. Limiting impact forces when marching in boots at this speed has been shown to be possible to a limited extent only.

Speed marching has not yet been the subject of research at the department. During speed marching, a participant alternates from marching to running and vice versa. In the literature, the speed at which a runner switches from marching to running is called the walk-to-run transition. This speed is usually between 6.84 and 7.56 km/h (corresponding to 1.9-2.1 m/s) [6]. The step rate is usually between 134 and 141 steps per minute [7]. However, the studies are based on measurements of civilian athletes in running shoes.

Why a runner switches from marching to running is not exactly known. Presumably the feeling of muscle exertion plays a role. At a velocity near the walk to run transition the legs will go through smaller ranges of movement while running than while marching [6].

The following is already known about marching with a backpack and a rifle: by carrying the weapon with two hands, the arms are limited in movement, so that a natural arm swing is no longer possible. The impact peak (a vertical ground reaction force representation) increases due to the limitation of the arms and due to the weight of the weapon [8].

Recent research clearly indicates that the accumulation of impact forces plays a role in the development of overuse injuries of the lower extremity [9]. Knowledge of the ground reaction forces during speed marching, in particular the optimal speed of switching from marching to running, can lead to advice that can reduce musculoskeletal load. It may eventually be possible to draw up a general guideline for the alternation of running and marching when performing speed marches based on a few body characteristics, for example body height or leg length. The walk-to-run transition speed for a service member in boots with a backpack and a rifle is not yet known. It is also not known whether marching at this speed or running produces less vertical ground reaction forces. The following research questions were therefore formulated for this study:

1. What is the walk-to-run transition speed for marching in military boots with standard 25 kg load including a (practice) rifle?

2. What are the vertical ground reaction forces of marching and running at the speed of the walk-to-run transition?

Methods

The study involved a one-time series of measurements on an instrumented treadmill, in a running laboratory of 12 healthy, male military service members in boots with a standard load of 25 kilograms including a backpack, a tactical vest, and a practice rifle, see Figure 1.

Participants were invited by name or through acquaintances to the units where the first author works as a medical doctor. Inclusion criteria were age 18-40 years-old, height 1.75-1.90 meters, male sex, experience with speed marching. An exclusion criterion was an injury of the lower extremity in the last three months. Participants all gave permission to process the measurement data anonymously in a public publication.

The following biometric data were collected from each participant: age, body height (cm), body weight (kg)

Figure 1: The treadmill used in this study, with a participant. Note the backpack and the (practice) rifle.

and length of the right leg (cm). Body height and weight were determined at a combined measuring station of the brand Kern (Balingen, Germany). The Body Mass Index (BMI) was calculated (BMI = weight/(height^2)). Leg length was defined as the distance from the anterior superior iliac spine to the inferior pole of the medial malleolus and was measured usinga tape measure with the subject supine on an examination table.

A treadmill measurement was then taken twice:

Treadmill measurement 1: Determination of the walk-to-run transition speed

The participant steps on the treadmill. Over a period of two minutes, the treadmill speed is gradually increased to the test starting speed. The test starting speed of the march is 6.5 km/h. At 30-second intervals the speed of the treadmill is increased by 0.1 km/h. The instructions to the participants are always the same: "transition from marching to running at your own discretion". Once the transition has been completed, the participant continues to run for one minute with no change in treadmill speed. The test is then terminated as the desired value, the walk-to-run transition speed, has been determined. After that, the participants receive at least five minutes of rest. It was estimated in advance that treadmill measurement 1 would take a maximum of 12 minutes (up to and including a marching speed of 8.5 km/h).

Treadmill measurement 2: Determination of the vertical ground reaction forces

The participant steps on the treadmill. Over a period of two minutes, the treadmill speed is gradually increased to the walk-to-run transition speed, which was determined per individual in treadmill measurement 1. The participant walks for one minute at the walk-to-run transition speed. The vertical ground reaction forces are measured in the last 30 seconds of this minute. Then the participant runs for one minute at the same speed, the last 30 seconds of this minute the vertical ground reaction forces are measured. Treadmill measurement 2 takes a maximum of four minutes.

The instrumented treadmill is made by H/P/Cosmos (Nussdorf, Germany), the software for controlling the treadmill and the presentation of the measured values is made by Zebris (Isny am Allgau, Germany). The following biomechanical parameters were taken from the treadmill measurements to describe marching and running:

1. Step length (centimeters)
2. Step frequency (steps per minute)
3. Vertical forces under the forefoot (Newton)
4. Vertical forces under the midfoot (Newton)
5. Vertical forces under the heel (Newton).

The raw data collection was done using specifically designed research forms (on paper). The data was then entered into a custom database in Excel. The database was anonymized and will be deleted after one year in accordance with current national privacy laws.

The collected data were analyzed with descriptive statistics, number, mean, lowest value (minimum), highest value (maximum), and standard deviation. Subsequently, it was tested whether the vertical ground reaction forces at the walk-to-run transition speed differ significantly during marching and running and how strong the correlation is between the biometric data and the walk-to-run transition speed. Significance was set at 0.05. Correlation was defined as follows: 0.1 = weak, 0.3 = medium; 0.5 = strong. The collected data is shown with summary tables.

Results

Table 1 shows the biometrics of the 12 male participants in the study. Table 2 shows the measurements at the walk-to-run transition speed. The walk-to-run transition speed averaged 7.4 km/h (SD 0.5). At this speed, marching was characterized by greater step length and lower step frequency as compared to running.

Table 1: Biometrics of the 12 male participants in the study.

Participants (n = 12)	Average	Min-max	SD
Age (years)	32.9	26-39	5.0
Body Height (cm)	180.9	177-187	3.4
Body Weight (kg)	83.3	74-92	5.7
Body Mass Index	25.5	21.4-28.4	1.9
Leg length, right leg (cm)	93.9	84-101	5.3

n: number; Min: minimum; Max: maximum; SD: standard deviation; cm: centimeter; kg: kilogram

The correlation between leg length and the walk-to-run transition speed is strong (r = 0.56), the correlation between body height and the walk-to-run transition speed is stronger (r = 0.82).

Table 3 shows the vertical ground reaction forces at the walk-to-run transition speed during marching and running for three parts of the foot (three parts of the sole of the boot): The forefoot, midfoot and heel. The mean forces on the heel were found to be significantly lower while running than while marching.

Discussion

In this study, the walk-to-run transition speed for marching in military boots was determined on a treadmill. This was done on 12 healthy, male military service members who were experienced in speed marching and with a standard load of 25 kilograms, which included a backpack, a tactical vest and a practice rifle. The vertical ground reaction forces were also measured during both marching and running at the walk-to-run transition speed. The key findings of the study are that the walk-to-run transition speed on a treadmill was 7.4 km/h and that at this speed the vertical ground reaction forces on the heel are smaller while running than while marching.

When the findings are compared with previous results in the literature, the walk-to-run transition

Table 2: Measurements at the walk-to-run transition speed.

Participants (n = 12)	Average	Min-max	SD
Walk-to-run transition speed (km/h)	7.4	6.9-8.4	0.5
Step length while marching (cm)	90.3	81-103	5.7
Step length while running (cm)	76.6	70-87	5.4
Step frequency while marching (steps/min)	136.7	131.1-147.4	4.2
Step frequency while running (steps/min)	161.4	151.3-194.4	7.4

n: number; Min: minimum; Max: Maximum; SD: standard deviation; km/h: kilometers per hour; cm: centimeter; steps/min: steps per minute

Table 3: Vertical ground reaction forces at the walk-to-run transition speed, during marching and running, for three parts of the sole of the boot.

Participants (n = 12)	Average	Min-max	SD
vGRF on the forefoot while marching (N)	978.2	840-1099	85.9
vGRF on the forefoot while running (N)	1005.4	665-1144	176.2
vGRF on the midfoot while marching (N)	427.9	349-591	101.3
vGRF on the midfoot while running (N)	507.3	228-841	174.4
vGRF on the heel while marching (N)	849.8*	757-1057	98.1
vGRF on the heel while running (N)	619.2*	288-768	138.1

Note: * the mean forces on the heel are significantly lower while running than while marching.

*p = 0.00; a significant difference between factors indicated.

n: number; Min: Minimum; Max: maximum; SD: standard deviation; vGRF: vertical Ground Reaction Forces; N: Newton speed is higher than expected. After all, the walk-to-run transition speed for runners, in sports shoes and without additional load is between 6.84 and 7.56 km/h (1.9-2.1 m/s) [6]. When weighing this task down with boots, a backpack, a tactical vest and a (practice) rifle, it is expected that the walk-to-run transition speed will be lower, like the findings when walking uphill [10]. For well-trained military service members, 7.4 km/h is not an extreme marching speed. In a study of very fit British soldiers investigating blood lactate during marching and running in boots with 20 kilograms of luggage, marching speeds were recorded up to 8.4 km/h [11]. Experienced military personnel may have taught themselves to increase the walk-to-run transition speed, under the motto: "big steps bring you home faster". It should be noted, however, that taking extended, forced steps, is associated with the development of an overuse injury of the legs called chronic exertional compartment syndrome, particularly of the anterior compartments [12]. Some military medical doctors might say: "big steps bring you to a doctor faster".

This is not the first study to compare biomechanical aspects of marching and running at the same speed. In a study of 23 recreational athletes, 13 men (average age 25-years-old) and 10 women (average age 28-years-old), it was found that vertical ground reaction forces were 49.6% higher while running at 7.2 km/h as compared to walking. The authors reported that subjects straightened up when running and adopted a springy and jerky style of running [13]. The findings in the current study are opposite, the vertical ground reaction forces at a speed of 7.4 km/h were significantly lower while running than while marching. Apparently, the experienced military service members in this study have developed a running technique in boots in which the vertical ground reaction forces are less while running than while marching.

It follows from these findings that it is more favorable for military personnel to run at the speed of the walk-to-run transition than to march with regard to impact forces when carrying out speed marches with a backpack, a vest and a rifle. Because vertical ground reaction forces play a causal role in the development of overload injuries [9], it may be desirable to switch from marching to running earlier and at a lower speed. This must be explored in future research. Ideally, for each person who must participate in speed marching on a regular basis, the optimal walk-to-run transition speed should be determined based on personal measurements. If this is not feasible due to time investment and costs, researchers should design a guideline recommending a walk-to-run transition speed for service members participating in speed marching with and without additional load. Based on the findings of this study, body height should play an important role in recommending walk-to-run transition speed.

This study has limitations. It concerns a small, specific group of participants, namely fit military service members experienced in speed marching. The findings should be seen as initial results, and the statistic should be interpreted with caution. It is recommended to include more participants in follow-up research to reduce the chance of incidental findings. It is also a limitation that no women participated. This often happens in Defense research, because only 10% of the employees are women. Research with female service members is necessary in the future.

Despite the limitations mentioned, this research is valuable. It provides insight into some biomechanical aspects of speed marching and a first impression of the advice that can be given to reduce the musculoskeletal load of this military occupational activity.

Conclusion

The walk-to-run transition speed, measured in 12 healthy and experienced military service members during speed marching in boots with 25 kg standard load (backpack, tactical vest and rifle), is 7.4 km/h (SD 0.5 km/h). At the speed of walk-to-run transition vertical ground reaction forces were lower while running than while marching in this particular population and activity. Alternating from marching to running at a speed below the self-selected walk-to-run transition speed may reduce vertical ground reaction forces when marching in boots. Further research into the optimal transition speed from marching to running in military boots is warranted.

Acknowledgement

The authors are grateful to the participants of this study and to Timothy L. Miller, MD, FAAOS, the Ohio State University Wexner Medical Center Sports Medicine for proofreading the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Sources of Support

Both authors have produced this work for their employer, The Royal Netherlands Army, no outside sources of support were received.

Statement of Authors Contributions

Study initiative and design WZ, study execution EM, writing of manuscript WZ and EM. Both authors concur in the submission of this manuscript for publication.

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