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The Effect of Load Carrying on Gait Kinetic and Kinematic Variables in Soldiers with Patellofemoral Pain Syndrome

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Abstract: Individuals suffering from patello-femoral pain syndrome (PFPS) exhibit altered gait parameters compared with healthy individuals. As soldiers carry heavy equipment, the extra load might further alter gait pattern. The aim of this study was to investigate the effect of load carrying on kinetic and kinematic variables in soldiers with PFPS compared with controls. The sample comprised 23 active-duty infantry soldiers (10 with bilateral/13 without bilateral PFPS, mean age: 20.4 ($\pm$0.5) years, height 179 ($\pm$5.8) cm, weight 76 ($\pm$6.9) kg). The participants walked barefoot on a 10 m walkway with and without loading equipment. The equipment added 50% to each participant's body mass. Gait kinematic and kinetic variables were assessed by the VICON three-dimensional motion analysis system and two force plates. Weight carrying increased joint maximal angles, mean peak moments and double support and decreased single support and walk speed in both groups, without differences between groups ($p > 0.05$). The only difference between groups was in the hip adduction angle without a load ($p < 0.05$); no difference was observed while carrying the load. Kinematic and kinetic differences in gait were detected between weight and non-weight conditions, yet there was no effect of PFPS. Further studies with subjects performing different tasks are essential to examining the effect of PFPS and load among soldiers.

Keywords: walking; knee pain; weight; load

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1. Introduction

Certain military tasks demand load carriage due to mission characteristics or terrain conditions. Infantry soldiers carry a considerable amount of equipment that is vital to their assignments and survival. However, carrying overweight loads may lead to early fatigue and injuries [1–3]. Over the past few decades, a constant increase in the combat loads carried by soldiers has been observed; presently, these loads may reach 75% of the soldier's weight [1].

Research on load carrying in military populations has found altered gait patterns, including changes in spatiotemporal and kinematic parameters. These changes include forward trunk leaning, a reduction in lumbar lordosis, increased pelvic tilt, decreased pelvic rotation and increased knee and hip flexion angles at foot strike [3–6].

Combat soldiers frequently suffer from musculoskeletal overuse injuries during routine training, resulting in sick leave, a limitation of participation in training and discharge from duty [7,8]. The more common overuse injuries amongst soldiers are lower back pain, knee pain, shin splints, tibia stress fractures, ankle sprains and metatarsalgia [1,2]. Knee injuries are the second most frequent injury, with patello-femoral pain syndrome (PFPS) being the most common, with a prevalence ranging from 7% to 15% [2,9].

Although widely investigated, the exact etiology of PFPS remains unclear. PFPS has been defined as local knee pain involving the peri-patellar area [10,11]. The common functional complaint is pain experienced during physical activities that include knee flexion such as climbing and descending stairs, performing squats and jumping, as well as after extended sitting. During knee flexion, an increment in force and load occurs on the patellofemoral joint, which further increases during functional activities [10]. Moreover, Glaviano et al. found that running causes a higher increment of pain compared with walking, as during running, an increment of compressive forces reaches 7–10 times the body mass on the patellofemoral joint [10].

Kinetic and kinematic studies have shown that individuals with PFPS exhibit altered gait parameters compared with healthy individuals, i.e., a reduction in cadence, decreased velocity, slower swing velocity and shorter step length [9,12]. Individuals with PFPS exhibit a reduction in knee flexion angle, a lower knee extensor moment, an increased knee abductor moment and an increased knee external rotation moment. These changes probably occur in order to reduce loading on the painful patellofemoral joint and might be the outcome of the individual to avoid pain [12–14]. Furthermore, it has been found that individuals with PFPS have decreased hip muscle strength, increased hip adduction and knee abduction and greater peak internal rotation movement [15–19]. Moreover, larger Q angles of the knees or greater knee valgus have been associated with patella-femoral instability, patellofemoral arthritis and lower hip muscle torque and lower function [20,21].

Although the literature describes a correlation between load carrying and musculoskeletal injuries, in general [4], there is a lack of evidence relating to the clinical correlation between load carrying and PFPS. As individuals with PFPS already exhibit changes in their gait parameters, by adding an extra load, their gait pattern might be further altered, thus placing the individuals at a greater risk for injury and pain. Therefore, the aim of this study was to investigate the effect of load carrying on kinetic and kinematic variables in soldiers suffering from PFPS relative to soldiers without PFPS.

Our hypothesis was that during load carrying, individuals with PFPS will exhibit greater changes in gait parameters compared with controls.

2. Materials and Methods

The study was approved by the Israel Defense Force's (IDF) medical research committee (#IDF-1181-2012). All subjects volunteered to participate in the study and signed an informed consent form prior to participation in the study.

2.1. Participants

The study sample included 23 male infantry soldiers on active duty from two chosen active units. Recruitment of participants was performed in coordination with the medical officials in the units and with their consent. All subjects had completed their basic and advanced training (at least 6 months on active duty), and they ranged in age from 18 to 21 years. Inclusion criteria for the research group (PFP group) were: current bilateral anterior knee pain for at least 6 weeks' duration; pain assessment during load carrying; score of at least 3 on a 0–10 visual analogue scale; pain provoked after 15 min of walking; pain elicited by patellar palpation; and positive patellofemoral joint compression (Clarke's test) [22]. Inclusion criteria for the control group were that the subjects had never experienced knee pain, present or past. Exclusion criteria for both groups were concomitant injury or pain arising from the lumbar spine or hip; previous knee surgery according to soldiers' medical records and self-report; knee ligament insufficiency; knee instability or patellar tendinopathy diagnosed by the physical therapist or the unit physician; and current use of medication/NSAID for pain. The research and control group included soldiers from the same army active units.

2.2. Research Protocol

The study was conducted at the Laboratory of Biomechanics, Academic College at Wingate Institute, Israel. All volunteers were recruited after being diagnosed by the unit physician/physical therapist with PFPS (according to the inclusion criteria). Prior to testing, the following anthropometric variables needed for the biomechanical model were examined: mass, height, knee width (widest part of the knee measured from the medial to the lateral joint space), ankle width (the medial to the lateral malleoli) and leg length (the medial malleoli to the anterior superior iliac spine).

The participants were asked to walk barefoot on a flat walkway (10 m) with and without loading equipment (Figure 1). Two force plates were located in the middle of the walkway (and for 5 m), embedded in the ground. The first 2 m and the last 2 m of the walkway allowed participants to maintain a normal walking pattern. The walking speed was self-selected according to the walking speed of the soldier with equipment during a training march. The instruction given was: "walk at the regular walking speed during training".

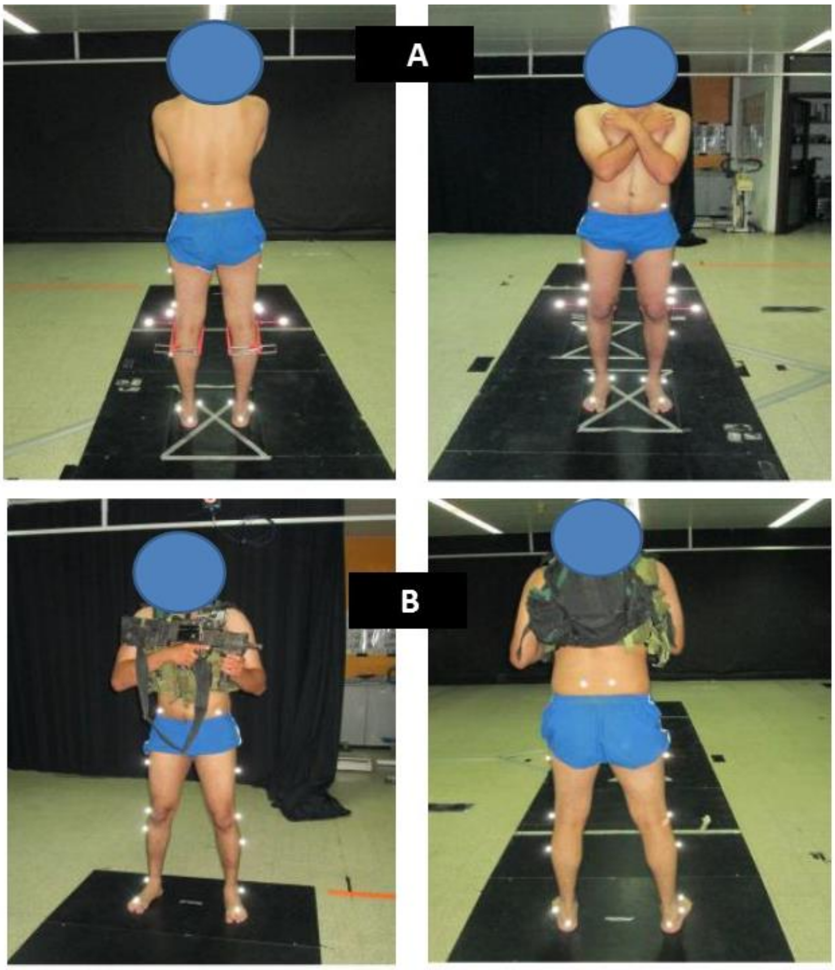

Figure 1. Markers on the subject's body: (**A**) without load, (**B**) with load.

The equipment included a rifle, battle vest and backpack. The weight in the pack was set so that the total additional weight of the gear was 50% of the soldier's body mass [7,23]. All participants were weighed prior to the trial to ensure adequate weight and load.

Practice walking trials were completed to allow for familiarization with the instruments and environment, including stepping on the force plates without changes in walking velocity. Subsequently, three successful trials were performed for each condition (with or without load). A successful trial was considered when the participant walked through the center of plates with both legs in a constant speed. The test condition order was randomly assigned, and data from both legs were recorded.

2.3. Instrumentation

The VICON three-dimensional motion analysis system along with 6 cameras operating at a sampling rate of 120 Hz (Vicon Motion Systems, Ltd., Oxford, UK) measured the kinematic variables (lower limb joint angles) during walking. Kinetic variables were collected using two force plates (Kistler 5223A) sampling the ground reaction forces in three axes, acting on each foot during the support phase at 960 Hz. Joint moments were calculated with Nexus software ((1.7.1) Vicon, Oxford, UK). A three-dimensional biomechanical model (lower-body model Plug-in Gait) by Vicon® was used. Retro-reflective markers were placed bilaterally to identify the posterior superior iliac spine, anterior superior iliac spine, mid-lateral thigh, mid-lateral shin, medial and lateral malleoli and a point bisecting the heel and base of the second metatarsus (Figure 1). The Vicon software and Plug-in Gait model directly calculate the kinematic model's joint centers from the measured XYZ marker positions on a frame-by-frame basis and specific subject anthropometric measurements. The model uses three or more points to define each segment [24,25]. The testing commenced with a static calibration phase; a knee alignment device (KAD) was used to evaluate the knee axis. During the dynamic trial, the KAD was removed, and a marker was placed on the lateral femoral condyle.

The force plates sampled the ground reaction force in Newton units. Parameters were normalized in relation to each soldier's weight (M/BW). The Vicon analysis system moment results were expressed in Newton meters divided by body mass (weight) (Nm/BW).

The following variables were tested during stance phase (defined from heel-strike to toe-off): (1) maximum angle (in degrees) during the stance phase for the following joint movements: hip adduction, hip internal rotation, knee flexion, knee valgus, knee internal rotation, foot pronation (Figure 2); (2) range of motion (in degrees) during the stance phase of the gait cycle for the following joint movements: hip adduction-abduction, hip internal–external rotation, knee flexion—extension, knee valgus–varus, knee internal–external rotation, foot pronation–supination; (3) mean peak moments (Nm/BW) in the stance phase (reference to movement is in terms of external torque): hip abduction/adduction, hip internal/external rotation, knee flexion/extension, knee vars/valgus, knee internal/external rotation, foot supination/pronation; (4) spatiotemporal variables: walking cadence (steps/minute), step time (second), one-leg support (seconds), two-leg support (seconds), stride length (meters), walking speed (meters/second).

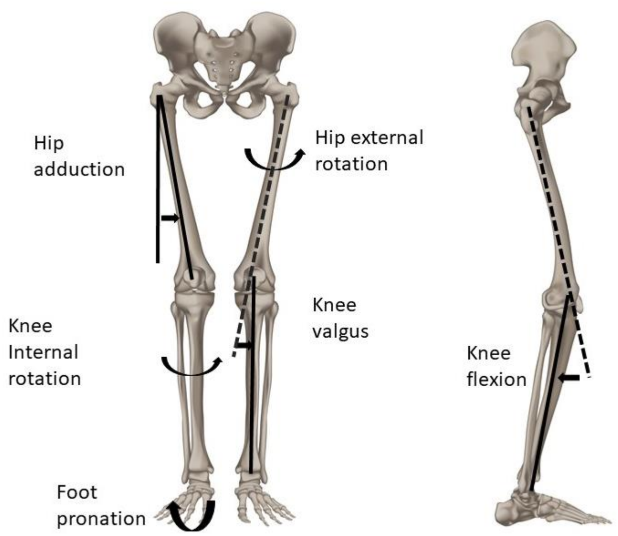

Figure 2. Diagrammatic representation of the joint angle measurements.

2.4. Statistical Analysis

Statistical analyses were determined with SAS version 9.4 for Windows. The data were first analyzed to evaluate the normal or non-normal distribution of all demographic parameters and outcome measurements. Continuous variables were reported by means and standard deviations. A three-way 2 (weight: with vs. without) × 2 (side: left vs. right) × 2 (group: PFPS vs. control) mixed-model repeated-measures analysis of variance (ANOVA) was run to examine the effect of weight, side and group on the measurements. Weight and side were within-subject measurements, and group was a between-subject measurement. Since a 3-way interaction was not significant, the analysis was narrowed to 3 types of two-way analyses (Table 1): (1) two-way 2 (weight: with vs. without) × 2 (group: PFPS vs. control) mixed-model repeated-measures ANOVA to examine the effect of weight and group on measures beyond the side effect; (2) two-way 2 (weight: with vs. without) × 2 (side: left vs. right) mixed-model repeated-measures ANOVA to examine the effect of weight and side on measures beyond the group effect; (3) two-way 2 (side: left vs. right) × 2 (group: case vs. control) mixed-model repeated-measures ANOVA to examine the effect of side and group on the measures beyond the weight effect. When the dual interaction was significant, a simple mean analysis was used to reveal the source of significance. A significant difference was determined as $p < 0.05$. The sample size was calculated according to initial results of 5 subjects in each group using the G-Power software. To obtain a statistical power of 90% at an alpha level of 0.05, 10 subjects in each group were required.

Table 1. Types of two-way analyses performed in the study.

	Weight: (With vs. Without)	**Group: (PFPS vs. Control)**	**Side: (Left vs. Right)**
weight: (with vs. without		✓	✓
group: (PFPS vs. control)	✓		✓
side: (left vs. right)	✓	✓	

3. Results

3.1. Study Sample

The research group included 10 active-duty combat soldier volunteers suffering from bilateral PFPS and a control group of 13 matched active-duty combat soldiers without knee pain. The mean age in the PFPS group was 20.4 (±0.5) years, mean height was 181.4 (±6.8), and mean body mass was 76.3 (±7.8) Kg. The mean age in the control group was 20.4 (±0.6) years, mean height was 178.77 (±4.7) cm, and mean body mass was 75.8 (±6.5) kg. No significance differences were found between the PFPS and control groups in mean age, height or body mass ($p > 0.05$).

3.2. Maximal Joint Angle

The results of the maximal joint angles during walking are summarized in Table 2. A significant difference with a large effect in the maximal angle was observed between load and no-load conditions in all examined parameters (greater in the load condition) ($p < 0.05$, $\eta 2p > 0.2$). There was a significant large effect of the interaction between group and condition in the hip adduction angle ($p = 0.029$, $\eta 2p = 0.207$). In the PFPS group, the mean maximal hip adduction angle was 4.51° and 4.64° without and with weight compared with 2.59° and 4.92° in the controls (Figure 3), thus implying that without load, a significant difference was found between groups, whereas while carrying a load, no difference was observed. No other differences between groups were found ($p > 0.05$). Although not significant, all angles were higher amongst the PFPS group compared with the controls (with and without load). No interaction between weight carrying and dominant leg or between weight carrying and leg side (left or right) was found, without differences between groups.

Table 2. Joint maximal angle parameters with and without load according to research groups and load condition (right leg, in degrees).

	PFPS Group (N = 10)		Control Group (N = 13)		*p* Value (between Load vs. No Load) (Partial Eta Square η2p)	*p* Value (between Research Groups) (Partial Eta Square η2p)	*p* Value (Interaction Group X Load (Partial Eta Square η2p)
	Without Load $\overline{X}$ (±SD)	With Load $\overline{X}$ (±SD)	Without Load $\overline{X}$ (±SD)	With Load (±SD)			
Hip adduction	4.51 (2.10)	4.64 (3.07)	2.59 (2.56)	4.92 (2.30)	0.017 * (0.244)	0.399 (0.034)	0.029 * (0.207)
Hip internal rotation	7.53(8.23)	9.80 (9.00)	5.21 (4.22)	6.88 (4.76)	0.018 * (0.238)	0.455 (0.027)	0.718 (0.006)
Knee flexion	26.49 (4.35)	29.12 (5.97)	24.20 (4.94)	26.92 (4.28)	0.001 * (0.411)	0.260 (0.060)	0.945 (0.000)
Knee valgus	8.51 (6.51)	10.57 (3.97)	7.68 (2.67)	9.03 (2.40)	0.003 * (0.344)	0.469 (0.025)	0.498 (0.022)
Knee internal rotation	11.82 (7.84)	13.75 (5.79)	10.44 (5.93)	11.46 (4.52)	0.004 * (0.336)	0.541 (0.018)	0.180 (0.084)
Foot pronation	1.57 (9.16)	3.35 (9.62)	0.56 (7.78)	2.4 (6.72)	0.028 * (0.210)	0.776 (0.004)	0.971 (0.009)

* Significant difference ($p < 0.05$).

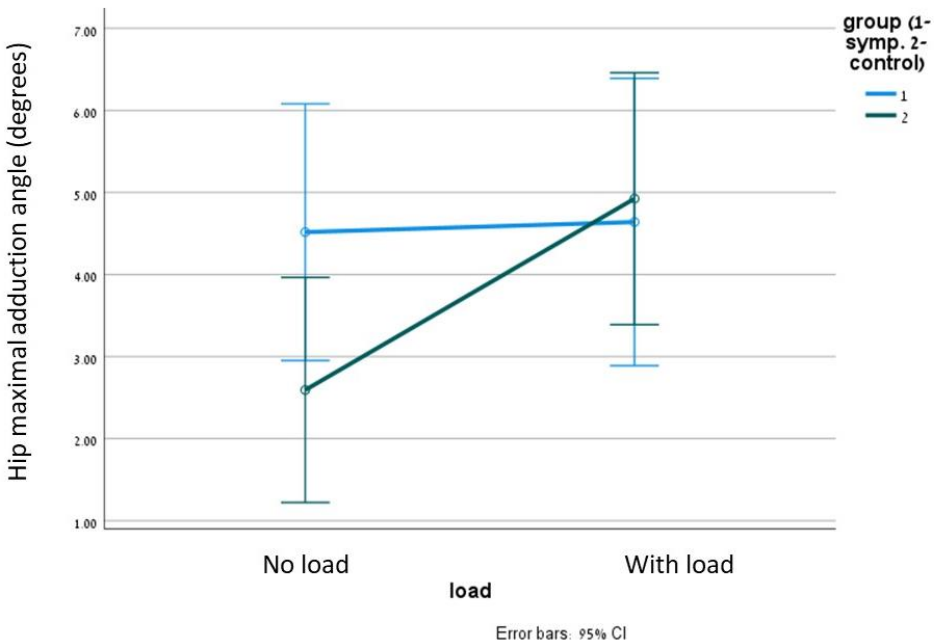

Figure 3. Hip joint adduction maximal angle (in degrees) according to the PFPS, controls and load conditions (right leg).

As no interaction with leg (left vs. right, dominant vs. no dominant) was found, all tables in the results part present the results of the right leg only (similar results were obtained for the left leg).

3.3. Joint Range of Motion

The results of the joints' range of motion during walking are summarized in Table 3.

There was a significant large effect of load on hip adduction–abduction range of motion ($p < 0.001$, η2p = 0.600), as well as on foot pronation—supination ($p < 0.05$, η2p = 0.412), which demonstrated a larger range of motion during walking with a load compared with the no-load condition. No effect of load carrying was found on other measured variables ($p > 0.05$). There was a significant large effect of group ($p = 0.041$, η2p = 0.185) on adduction–abduction range of motion. This implies that the research group (PFPS) had a smaller hip range of motion. There was a significant interaction between group and condition in the hip adduction–abduction range of motion (p = 0.025, η2p = 0.217). In the PFPS group, the mean hip adduction–abduction range of motion was 11.20 (±2.13)° and 13.2 1(±2.24)° without and with weight compared with 11.98 (±1.72)° and 16.99 (±4.38)° in the controls (Figure 4). This suggests a larger adduction–abduction range of motion in the control group. No other differences were found between groups regarding joint range of motions. No interaction between weight carrying and dominant leg or between weight carrying and leg side (left or right) was found, without a difference between groups.

Table 3. Joint range of motion parameters with and without load according to research groups and load condition (right leg, in degrees).

	PFPS Group (N = 10)		Control Group (N = 13)		*p* Value (between Load vs. No Load) (Partial Eta Square η2p)	*p* Value (between Research Groups) (Partial Eta Square η2p)	*p* Value (Interaction Group X Load) (Partial Eta Square η2p)
	Without Load $\overline{X}$ (±SD)	With Load $\overline{X}$ (±SD)	Without Load $\overline{X}$ (±SD)	With Load $\overline{X}$ (±SD)			
Hip adduction-abduction	11.20 (2.13)	13.21 (2.24)	11.98 (1.72)	16.99 (4.38)	<0.001 * (0.600)	0.041 * (0.185)	0.025 * (0.217)
Hip internal–external rotation	13.61 (4.77)	14.00 (3.21)	11.85 (4.22)	13.05 (1.79)	0.252 (0.062)	0.331 (0.045)	0.561 (0.016)
Knee flexion–extension	29.65 (5.00)	29.95 (5.24)	28.30 (6.79)	29.21 (5.54)	0.481 (0.024)	0.649 (0.010)	0.724 (0.006)
Knee valgus–varus	6.96 (5.38)	7.21 (3.55)	4.71 (2.12)	5.82 (1.67)	0.202 (0.076)	0.174 (0.086)	0.421 (0.031)
Knee internal–external rotation	15.08 (4.75)	16.15 (3.95)	13.57 (4.36)	13.06 (3.36)	0.572 (0.015)	0.180 (0.084)	0.123 (0.110)
Foot pronation–supination	21.70 (7.74)	24.14 (6.76)	18.06 (6.18)	22.52 (4.77)	0.001 * (0.412)	0.369 (0.039)	0.398 (0.034)

* Significant difference ($p < 0.05$).

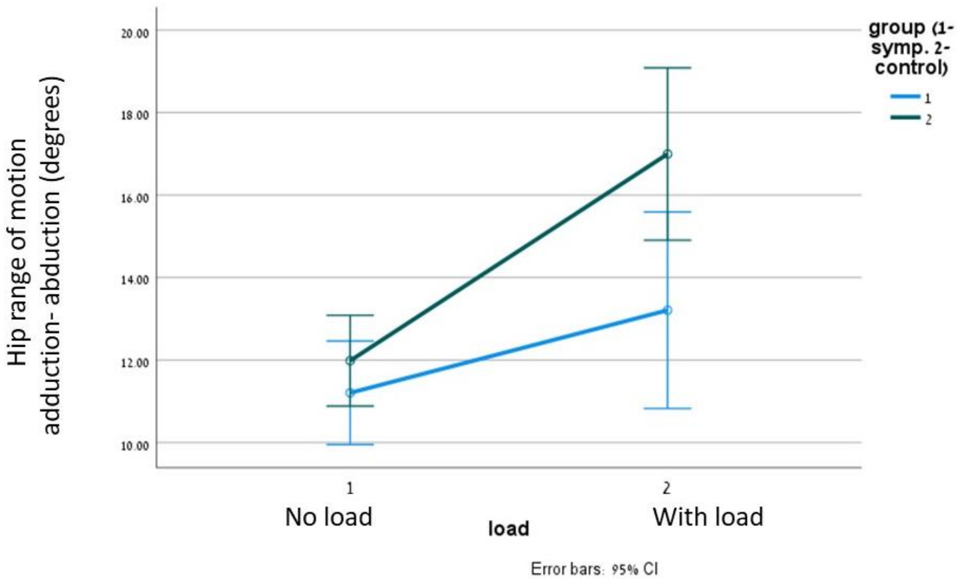

Figure 4. Hip joint range of motion adduction–abduction (in degrees) according to the PFPS, controls and load conditions (right leg).

3.4. Mean Peak Moments

The results of the peak moments are summarized in Table 4. There was a significant large effect of load on mean peak moments in both groups ($p < 0.05$, η2p > 0.3), suggesting greater moments of hip adduction, hip internal rotation, knee valgus (Figure 5) and internal rotation with load. No differences between groups were observed ($p > 0.05$). No interaction between weight carrying and group, weight carrying and dominant leg or weight carrying and leg side (left or right) were found, without a difference between groups.

Table 4. Mean peak moments with and without load according to research groups and load condition (right leg, in Nm/BW).

	PFPS Group (N = 10)		Control Group (N = 13)		*p* Value (between Load vs. No Load) (Partial Eta Square η2p)	*p* value (between Load vs. No Load) (Partial Eta Square η2p)	*p* Value (Interaction Group X Load) (Partial Eta Square η2p)
	Without Load $\overline{X}$ (±SD)	With Load $\overline{X}$ (±SD)	Without Load $\overline{X}$ (±SD)	With Load $\overline{X}$ (±SD)			
Hip adduction	0.85 (0.28)	1.01 (0.34)	0.75 (0.28)	1.18 (0.51)	0.005 * (0.315)	0.735 (0.006)	0.155 (0.094)
Hip internal rotation	0.17 (0.05)	0.21 (0.77)	0.16 (0.05)	0.21 (0.10)	0.001 * (0.433)	0.970 (0.000)	0.791 (0.003)
Knee flexion	0.89 (0.35)	0.99 (0.48)	0.75 (0.39)	0.86 (0.48)	0.089 (0.132)	0.451 (0.027)	0.857 (0.002)
Knee valgus	0.76 (0.29)	1.00 (0.50)	0.66 (0.32)	1.08 (0.64)	0.002 * (0.368)	0.965 (0.000)	0.356 (0.041)
Knee internal rotation	0.15 (0.06)	0.18 (0.08)	0.16 (0.06)	0.24 (0.12)	0.006 * (0.310)	0.234 (0.067)	0.197 (0.078)
Foot pronation	0.07 (0.06)	0.10 (0.09)	0.04 (0.03)	0.05 (0.05)	0.119 (0.112)	0.115 (0.114)	0.423 (0.031)

* Significant difference ($p < 0.05$).

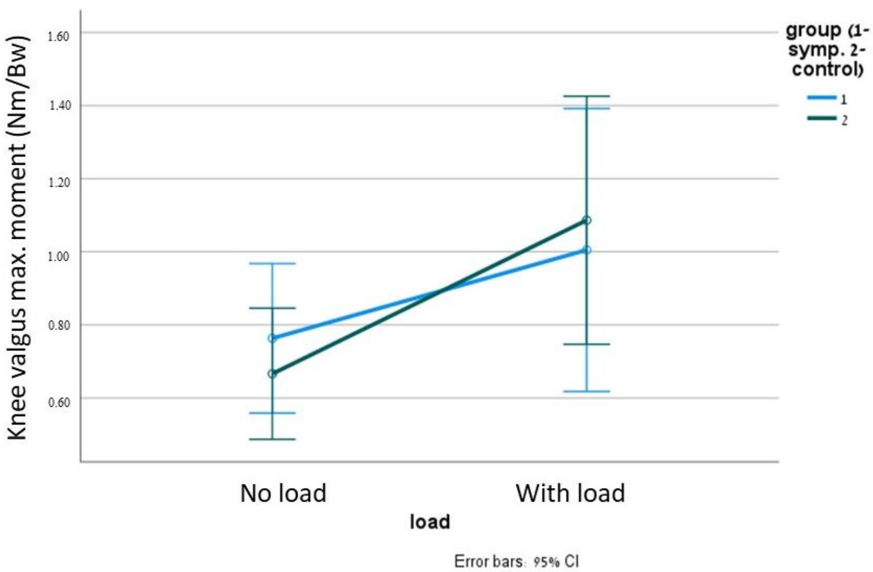

Figure 5. Maximal knee joint valgus moment in both groups.

3.5. Spatiotemporal Parameters

The results of the spatiotemporal parameters according to both groups are summarized in Table 5. A significant difference with a large effect was found between load and no-load conditions ($p < 0.05$, η2p > 0.4)) in the following variables: single- and double-leg support, stride length and walking speed, which thereby indicated that with load, the single-leg support decreased, whereas the double-leg support time increased, the stride length was shorter, and the walking speed decreased. No difference between conditions was found in the other variables measured or between groups, and no interaction was found between load conditions and research groups. No interaction between weight carrying and dominant leg or between weight carrying and leg side (left or right) was found, without a difference between groups ($p > 0.05$).

Table 5. Spatiotemporal parameters according to research groups and load condition.

	PFPS Group (N = 10)		Control Group (N = 13)		*p* Value (between Load vs. No Load) (Partial Eta Square η2p)	*p* Value (between Load vs. No Load) (Partial ETA Square η2p)	*p* Value (Interaction Group X load) (Partial Eta Square η2p)
	Without Load ($\overline{X} \pm SD$)	With Load ($\overline{X} \pm SD$)	Without Load ($\overline{X} \pm SD$)	With Load ($\overline{X} \pm SD$)			
Stride time (sec)	0.88 (0.05)	0.89 (0.05)	0.88 (0.04)	0.88 (0.06)	0.173 (0.091)	0.763 (0.005)	0.772 (0.004)
Stride length (m)	1.67 (0.07)	1.60 (0.07)	1.70 (0.10)	1.64 (0.11)	0.001 * (0.450)	0.780 (0.040)	0.780 (0.004)
Single support (sec)	0.37 (0.02)	0.36 (0.02)	0.37 (0.02)	0.36 (0.02)	0.001 * (0.413)	0.716 (0.007)	0.674 (0.009)
Double support (sec)	0.138 (0.02)	0.184 (0.03)	0.133 (0.19)	0.175 (0.03)	<0.001 * (0.767)	0.514 (0.022)	0.696 (0.008)
Walking speed (m/sec)	1.87 (0.15)	1.76 (0.16)	1.90 (0.79)	1.82 (0.18)	0.001 * (0.407)	0.488 (0.024)	0.602 (0.014)
Cadence (steps per min)	136.29 (9.09)	134.00 (7.96)	136.78 (7.61)	135.95 (8.91)	0.196 (0.082)	0.769 (0.004)	0.671 (0.009)

Results are presented for the right leg for stride time and length, single and double support. * Significant difference ($p < 0.05$).

4. Discussion

The aim of the current research was to examine the effect of weight carrying on gait parameters in infantry soldiers suffering from bilateral PFPS compared with infantry soldiers without PFPS.

Though load carrying was found to effect most of the examined parameters, an effect of PFPS on gait was not found; thus, the results of this study are in line with several previous studies that found inconsistent evidence as to the association between kinematic, muscle strength and peak moment [11,26,27]

Possible explanations for the non-significant differences between the PFPS group and the controls in our study might be associated with the task examined and the participants' characteristics. This study examined gait, yet different tasks, such as a single leg squat, drop jump, step down and single-leg jump, might better challenge the participants and reveal group differences. The participants were male soldiers who were relatively young. Presumably, they were accustomed to carrying loads and were strong enough to cope with the load and their chronic pain, as they had been previously practicing for a few months under the aforementioned conditions. Some studies that found altered joint kinematic and kinetics amongst PFPS participants [16] examined a female population [11], as PFPS is considered to be more common amongst females [28]. Furthermore, the inclusion diagnosis criteria might have influenced the results, as the soldiers did not complain of severe pain while performing their training.

In the present study, carrying load increased the hip adduction angle in the controls, whereas only a minimal change was observed in the PFPS group; thus, the differences between the PFPS and control groups lessened during load carrying. Moreover, the hip adduction–abduction range of motion was greater in the load condition in the controls compared with the PFPS group. Possibly, the extra load did not worsen the changes in the PFPS group, but rather decreased them in order to supply the joints and the body with more stability and a protective mechanism. Moreover, in previous studies, other changes also occurred during load carrying, such as a reduction in lumbar lordosis and trunk forward lean [7,29]. It should also be considered that due to the high intensity of training during military service and the higher physical requirements needed to carry a heavy load carriage, soldiers respond differently from civilians and should be separately studied.

It should also be noted that PFPS is a multifactorial condition with an idiopathic etiology and is usually quite insufficient in revealing the individual's exact source of pain [30,31]. As several anatomical structures can be diagnosed as the source of pain (i.e., synovium, lateral retinaculum, subchondral bone, the infrapatellar fat pad) [31], there is a large heterogeneity between individuals suffering from PFPS in symptoms and function. It can be suggested that carrying a load impacts every joint of the body (trunk and extremities), and in order to cope with the extra load, individuals with PFPS respond differently. This issue should be further examined.

Load carrying was found in the present study to alter gait spatio-temporal parameters among infantry soldiers with no differences between the PFPS and control groups, implying that with a load, single-leg support decreased, whereas double-leg support time increased, the stride length was shorter, and the walking speed decreased. These finding are in line with other studies on a population of soldiers [4,5,7,32,33]. The parameters of gait kinetic and kinematics were also found to change due to load carriage, implying greater maximal joint angles, a larger range of motion (adduction–abduction, foot pronation–supination) and greater peak moments during the load condition. Attwells et al. [7] also examined the effect of different load conditions (an increase in load weight from 8, 16, 40 to 50 kg) on gait and posture. The authors found differences between conditions, suggesting that the amount of the weight and its position on the body might influence gait pattern in differing ways.

The abovementioned changes during load carrying have been suggested as a protective mechanism of the human body in order to increase joint and postural stability during movement [32,33].

4.1. Limitations of Study and Future Studies

The main limitation of this study is the small sample size. In certain parameters in which a tendency was observed without a significant difference between groups, a larger sample size might reveal further differences and improve the validity of the results. Another limitation might be related to the inclusion criteria used in this study. Although we used a common diagnosis criterion for PFPS (including subjective and objective parameters), functional tests were not performed. Additional important data are missing, such as the severity and duration of pain. Although our sample represented greater pain >3 in the VAS scale, no other data were gathered or statistical analysis performed regarding pain characteristics.

Future studies should be conducted on a larger sample size using additional criteria, such as greater pain severity and higher irritability, as well as including an evaluation of muscle strength.

4.2. Strengths of the Study

This study used the VICON three-dimensional motion analysis system, which is considered to be the gold standard for gait analysis. The study examined a symptomatic group compared with a control group. The results of this study will help to determine how weight influences soldiers' gait and may lead to interventions or strengthening programs that can prevent pain and improve function and quality of life.

5. Conclusions

Weight carrying increased joint maximal angles, mean peak moments and double support, and it decreased single support and walk speed in both groups. These changes were similar amongst soldiers with and without PFPS. Future studies should include different and more challenging tasks.

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