Knee Kinematics and Kinetics during Descent of a Navy Ship Ladder

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INTRODUCTION
Knee disorders have been associated with walking on hard surfaces and stair ambulation [1]. Patellofemoral pain syndrome (PFPS) has been diagnosed as pain arising in the anterior part of the knee [2]. PFPS has been linked to military populations [2,3], particularly in individuals who regularly use the unusual and constrained configuration of Navy ship ladders [3]. From 1994 to 1996, the chief cause for orthopaedic medical disability boards at the Naval Medical Center in San Diego, CA was patellofemoral pain [3].

The relationship between descent of Navy ship ladders and external knee flexion moments is not well established. To the knowledge of this study, only one study has compared traditional stair to Navy ship ladder external knee moments [3]. The study found that knee flexion moments were greater in descent than ascent of the ship ladder [3]. Thus, the purpose of this study was to compare external knee flexion moments during the descent of Navy ship ladders to external knee flexion moments during descent of traditional staircases from the literature.

METHODS
A replica of the most commonly used ship ladder from the USS Forrest Sherman (DD931) was constructed. The tread depth, rise and overlap were 12.7cm, 22.54cm, and 0.4763cm, respectively. The angle of the steps was approximately 61°. The replica ladder contained 4 steps and attached to a platform that allowed the subjects to take a full step before hitting the force plates. Two Bertec force (Bertec, Columbus, OH) plates were rigidly fixed to the second and third steps from the ground.

Data were collected from three active duty Navy sailors, (2 males and 1 female, age=21±1.15 yrs, BMI=79.62±10.3 kg, height=170.7±13.6 cm). They did not have any previous history of knee surgery and were knee injury free for the past 6 months. A total of 50 retro reflective markers were attached to the feet, shanks, thighs, pelvis, trunk, back and shoulders of the subjects. Kinematic data were collected at 300 Hz using 8 VICON (Vicon, Oxford, UK) cameras and kinetic data were collected at 1200 Hz. VICON Nexus was used to simultaneously collect kinematic and kinetic data. Three trials of data were collected during the subjects’ descent of the ship ladder.

Kinematic and kinetic data were exported to Visual3D (C-Motion, Germantown, MD) for post processing. Knee moments and ground reaction forces were normalized to body mass.

RESULTS AND DISCUSSION
Peak knee flexion occurred at 99% of stance with an angle of 92.6 ± 7° (Figure 1A). The peak vertical ground reaction force occurred at 22% of stance with a magnitude of 10.8 ± 1 N/Kg and at 32 ± 6° of left knee flexion (Figure 1B). The peak external knee moment was 1.89 ± 0.15 Nm/kg and it occurred at 76% of stance and at 67 ± 5.5° of knee flexion (Figure 1C).

Peak knee flexion and peak knee moment were 91.8±5.9° and 0.91±0.21 Nm/kg, respectively when collected on conventional stairs at an angle of 31.3° [4]. While the peak knee flexion on conventional stairs was similar to the peak knee flexion on the Navy ship ladder, the peak knee moment on conventional stairs was 48% of the magnitude of the knee moment measured on the Navy ship ladder. Similarly, data collected on three males using a replica of a ship ladder with a tread depth, rise, overlap and incline of 15.2 cm, 24.1 cm, 2.5 cm and 58°, respectively, found higher knee moments than
reported on conventional stairs [3]. Specifically, the average peak external knee flexion moment was 252 ± 17 Nm, which was greater than the 147 Nm moment reported on conventional stairs [5].

These increased moments lead to increased patellofemoral joint forces [6]. Strategies to minimize these patellofemoral joint force and knee joint moments, such as strength training and/or bracing should be investigated. Also, decreasing the rise in the step and thus adding more steps could be helpful in reducing the knee joint moments and patellofemoral joint forces; however this may not be possible due to the space constraints within a ship.

CONCLUSIONS
The results confirm higher knee moments on navy ship ladders compared to traditional stairs [3]. Thus, if traditional stairs have the potential to cause knee disorders [1], sailors who spend time on hard deck surfaces and Navy ship ladders also have the potential to be at greater risk for similar knee disorders. Thus, potential approaches to reducing the moments and forces in the knee such as strength training and/or bracing and modifications to the rise of the step should be investigated.

REFERENCES

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Figure 1: A –The stance leg exhibits flexion without extension. B –The vertical ground reaction force from ‘heel strike’ to ‘heel off’, maximum forces occur during the beginning half of stance. C – The sagittal plane knee moment, normalized to body mass, is greatest during the latter half of stance.