INTRODUCTION

Changing the environment or introducing perturbations to the system can lead to a change in segmental coordination. Variability in the coordination of a movement permits exploration of the task, allowing for development of stable coordinative states over time [1]. When significant constraints and/or large enough perturbations are introduced, a shift between these attractor regions allows for an individual to adapt to changes in the motor activity while achieving the same goal [2,3]. Adaptations to small perturbations are dealt with mainly by variation, maintaining the same coordination pattern but temporarily deviating from the theoretical optimal or normal pattern [4]. Too little or too much variability may have implications for injury risk [6]. The relationship between stability and variability allows for individuals to both achieve persistence at completing a task and to change the motor output as needed when perturbations are introduced.

The purpose of this study was to examine the effects of introducing load and fatigue on lower limb gait coordination and the variation of that coordination. A better understanding of lower limb injury mechanisms may be derived from determining how coordination patterns change under loaded and/or fatigued conditions. Using mean absolute relative phase (MARP) as a measurement of coordination and deviation phase (DP) as a measure of variation within a coordinative strategy, the changes in inter- and intra-limb orientation were compared across conditions to determine if coordination or variation was altered due to the perturbations presented to the system. It was hypothesized that neither load nor fatigue would lead to significant changes in coordination.

METHODS

Twenty three male subjects were recruited from university student population convenience sampling. Following Army recruitment patterns, participants were 18-27 years of age and had a body mass index no greater than 28. Other exclusion criteria included current or previous military enlistment and current or previous musculoskeletal injury. Participants walked on the treadmill at a pace of 6km/h at a 0% incline under four different load/fatigue conditions. These conditions were:

1) unloaded-unfatigued (UU)
2) loaded-unfatigued (LU)
3) loaded-fatigued (LF) and
4) unloaded-fatigued (UL)

The loaded conditions refer to the participants carrying a 35 kg rucksack. The fatigued condition was induced by a fatiguing protocol completed between conditions 2 and 3. This protocol included loaded stepping, loaded heel raises, and maximal vertical jumping. This sequence of exercises was completed until the participants maximal vertical jump attempt fell to or below 80% of their original $V_{J \text{max}}$ height; at this point it was assumed that fatigue was reached [7]. This allowed for the fatigue protocol to be specific to each individual subject’s capabilities.

Data were collected in 10 trials of 5 seconds each during the final minute of each walking stage. The angular positions and velocities of the foot, shank, and thigh of both limbs were calculated. Phase portraits were generated and phase plant trajectories were utilized to determine phase angles. Relative phase values were calculated for inter-limb and intra-limb coordination by determining the
difference in phase values of relevant segments at each of 101 points in the gait cycle. The relative phase curves were averaged across all trials for each condition for all subjects [8].

In order to determine statistical differences, the curves were reduced to single numerical values of MARP and DP. The MARP is calculated by averaging the absolute values of the CRP curve for a given limb segment pair with a higher value indicating segments were more out of phase. The DP was calculated by averaging the standard deviation values of the CRP curve for a given limb segment pair with a higher value indicating more variable relationship between segments.

A repeated measures analysis of variance test ($\alpha = 0.05$) was utilized to test for differences in MARP and DP within participants across testing conditions.

RESULTS AND DISCUSSION

No significant changes in MARP were observed for any condition. Inter-limb DP at the ankle was significantly greater for LF than for UU and UF. Similar significance was seen at the knee with LF being greater than UU and UF. Only the shank-shank intra-limb pairing showed any significant variation differences, with UU being less than LF.

Participants tended to increase the variability in the chosen pattern instead of utilizing a new coordination pattern. The results suggest that with the combination of fatigue and load carriage, the variation in coordination is significantly higher than when not carrying the load no matter the state of fatigue.

The conditions utilized were designed to produce situations similar to military training exercises; a consistent gait velocity coupled with load bearing and fatigue. Results from this study revealed that some variability change did occur most often between the LF and UU testing conditions. It is important to note that coordination and variation values do not directly depend on each other. In other words, it is possible for MARP to change without a change in DP, and vice versa.

In this investigation, only sagittal plane angular position and velocities were assessed. It is important to note this because there may have been movement occurring in one of the other planes that was not represented with the data. An assessment of the frontal plane may have revealed greater hip abduction or excursion. This kind of movement may be viewed through the CRP assessment of the frontal plane, or possibly through more traditional gait parameters, such as steady step length and increased foot path length.

CONCLUSIONS

Coordination pattern did not change with the addition of load or fatigue relative to gait, but the variation in intra-limb coordination did increase. Future research should look further into the implications of variation changes with prolonged weight bearing gait tasks to fatigue.

REFERENCES


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