Postural Classification of Healthy Walking and the Attributing Muscle Force Generation Across Diverse Age Groups

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Introduction

Understanding the characteristics of healthy walking, which serve as normative data, is essential for identifying health-related pathologies and disorders. Although a few previous studies have examined the characteristics of healthy walking, a comprehensive analysis of walking posture and the attributing muscle force generation across diverse age and sex groups remains lacking. This study aimed to classify postural patterns in healthy human walking and reveal the attributing muscle force generation using an extensive gait database that includes individuals across a wide age range.

Methods

We used previously collected kinematic and kinetic walking data from 120 participants aged from 20s to 70s, with 10 males and 10 females in each age group [1]. Participants walked along a 10-meter walkway at a comfortable speed, and the data were acquired using a three-dimensional motion capture system combined with force plates. Principal component analysis was performed on the time-normalized three-dimensional pelvis, hip, knee, and ankle joint/segment angles throughout the gait cycle to extract key features of individual walking postures. Hierarchical clustering analysis was then applied to classify these principal components into several postural types during walking. Muscle force profiles of the lower and trunk muscle groups throughout a gait cycle were estimated using musculoskeletal simulation software (AnyBody Modeling System, version 7.4, Aalborg, Denmark), and compared with the clusters. Demographic information, such as age and biological sex, was also analyzed to understand the attributes of each cluster.

Results and Discussion

Walking postures were classified into three clusters. Clusters 1 included a higher proportion of male participants and were characterized by a larger posterior pelvic tilt and hip extension compared to the other clusters (Table1, Figure1-a, b). In contrast, Cluster 3 included more female participants and exhibited a larger anterior pelvic tilt and hip flexion. Cluster 2 featured a nearly equal number of younger male and female participants and showed average characteristics relative to the other clusters. The differences in muscle force profiles between clusters were primarily observed in the gluteal muscle group (Figure1-c, d). These results suggest that walking posture can be categorized into three types, with biological sex and age serving as the primary influencing factors. Additionally, this classification is further defined by the pelvic and hip movements, and these variations appear to be attributed to the activity of the gluteal muscle groups.

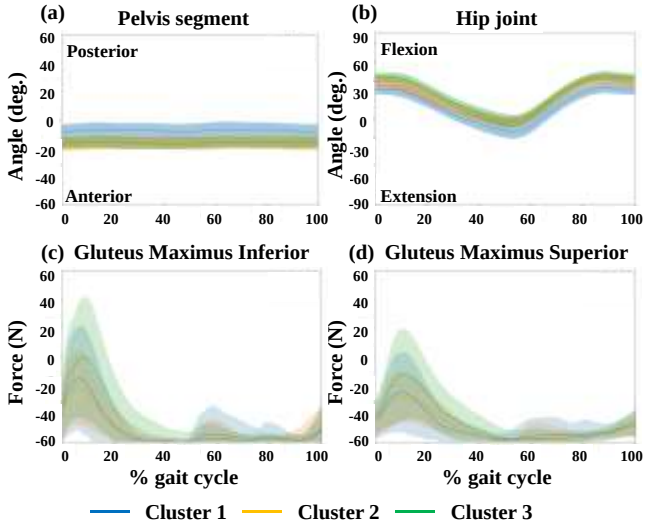

Figure1: Representative segment/joint angle and muscle force profiles for the clusters

Conclusions

These findings may be useful for identifying deviations from healthy walking postures, particularly those associated with pathological conditions or movement disorders

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References

[1] Kobayashi et al., 2019, AIST Gait Database 2019.

Table 1: Demographic information for the clusters

Cluster	Sex		Age							Height	Body mass
	Male (n)	Female (n)	20s (n)	30s (n)	40s (n)	50s (n)	60s (n)	70s (n)	Average (y/o)	Average (m)	Average (kg)
Cluster1	38	10	5	12	7	8	6	11	50.5	1.68	67.7
Cluster2	14	15	10	5	5	6	1	2	39.7	1.66	57.1
Cluster3	8	35	5	4	8	6	13	7	52.6	1.60	57.4