健康老人跨越障礙時下肢關節協調能力研究

Inter-joint Coordination of the Lower Extremities in Healthy Older Adults During Obstructed Gait

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摘要

十七位健康老人與年輕人行走並跨越三種不同高度的障礙物（10%、20% 及 30%的腳長）。我們利用一七台紅外線攝影機的動作分析系統量測運動學資料，取得矢狀平面的關節角度。各關節相角（φ）利用角速度（x'）與角位移（x）之切角表示之，即 $\varphi=\tan^{-1}(x'/x)$，相對相角則利用近端關節相角減遠端關節相角相求得（即 $\varphi_{hip\text{-}knee}$, $\varphi_{knee\text{-}ankle}$）。偏差相角值則用以代表關節間協調能力之穩定度。結果顯示，老人與年輕人相對相角模式類似，代表兩族群關節間協調模式類似。前腳跨越時，為了維持較大的腳與障礙物間隙，老人關節間協調能力之穩定度較年輕人差。後腳跨越時，老人關節間協調能力之穩定度與年輕人沒有差異，可能是因為相對於前腳跨越，後腳跨越時的力學需求較小，老人較容易達到此需求。

1、Introduction

Age-related changes in the sensorimotor and musculoskeletal systems are known to be responsible for the compromised ability of older adults in negotiating obstacles, a complex motor task that has been related to the high incidence of falls in the elderly [1]. Obstacle-crossing during walking is essentially a multi-joint movement, requiring precise swing foot control and a high level of inter-joint coordination of the stance and swing limbs. The stability of the coordination patterns, a fundamental feature of functional action [2], is also essential. Failure to meet these requirements, sometimes caused by diseases, may lead to falls. Study of the inter-joint coordination and the associated swing foot-obstacle clearance in healthy older adults during obstacle-crossing will be useful for a better understanding of the effects of aging on the control of this activity. Therefore, the purposes of this study were to determine and compare the patterns and stability of the inter-joint coordination between young and older adults during obstacle-crossing, and to study the obstacle-height effects on these potential differences.

2、Materials and Methods

Seventeen healthy elderly and 17 young adults walked and crossed obstacles of different heights (10%, 20% and 30% of leg length). Kinematic data were measured using a 7-camera motion analysis system (Vicon 512, Oxford Metrics Group, UK) at a sampling rate of 120 Hz. Toe-clearances were calculated as the vertical distances between the toe markers and the obstacle. Angular displacements in the sagittal plane were normalized such that the range of angular positions during movement lay between -1 and 1, with the midpoint located at zero. Angular velocity values were normalized by the maximum absolute velocity during the movement. Phase plots of normalized angular velocities (x') against normalized angular displacements (x) for each joint were then generated, and the phase angle (φ) was calculated as $\varphi=\tan^{-1}(x'/x)$. Relative phase angles (RPA) between two adjacent joints were then calculated by subtracting the phase angle of the distal joint from that of the proximal, namely $\varphi_{hip\text{-}knee}$ and $\varphi_{knee\text{-}ankle}$, respectively [3]. A parameter called the deviation phase (DP) was then calculated as the standard deviation of each point on the ensemble curve and then the standard deviations over the complete profile for the stance and swing phase for each obstacle height were averaged [4]. The Group and height effects on the DP variables and toe-clearances were tested using mixed ANOVA. The correlation between DP values and toe-clearances was determined by polynomial regression. A significance level of 0.05 was set for all tests. All statistical analyses were conducted using SPSS (Version 13.0, Chicago, IL).

3、Results & Discussion

Although the elderly have been found to have altered joint kinematics during obstacle crossing [5], they did not appear to change the way the lower limb joints were coordinated (Fig. 1-2). However, variability of the inter-joint coordination of the limbs increased, possibly due to increased toe-clearance (Table 1).

While the variability of the swing hip-knee and knee-ankle coordination was increased during leading limb crossing, only the variability of the knee-ankle coordination of the trailing stance limb was increased (Fig. 1-2). This may be explained by the increased toe-clearance, as indicated by the DP-clearance correlations (Table 1). With unaltered inter-joint coordination pattern during leading limb crossing, greater variability of the inter-joint coordination, in both the swing limb joints and the stance limb's knee and ankle, indicates that aging reduces the reliability of the way the lower limb joints are controlled during obstacle-crossing. This suggests that inter-joint coordination in the elderly during leading limb crossing may be less stable as compared to the young, and that necessary foot clearance and body balance may not be recovered reliably once perturbed, which could increase the chance of falls.

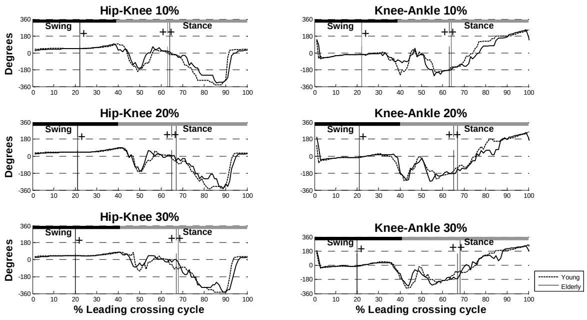

Fig. 1 The ensemble-averaged relative phase angles of the hip-knee and knee-ankle coordination of the leading (left column) and trailing (right column) swing limbs for the elderly (solid lines) and young (dashed lines) groups when crossing obstacles of 10%, 20% and 30% of leg length. '+' indicates leading swing toe crossing and '++' trailing swing toe crossing.

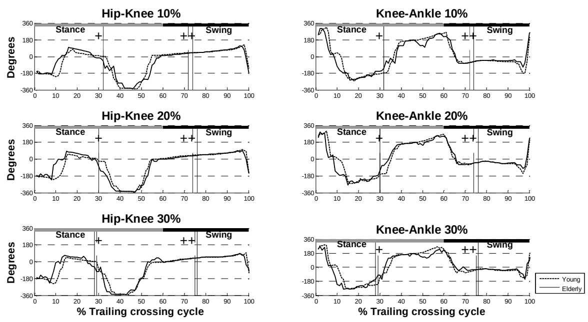

Fig. 2 The ensemble-averaged relative phase angles of the hip-knee and knee-ankle coordination of the leading (left column) and trailing (right column) stance limbs for the elderly (solid lines) and young (dashed lines) groups when crossing obstacles of 10%, 20% and 30% of leg length. '+' indicates leading swing toe crossing and '++' trailing swing toe crossing.

In contrast to the crossing of the leading limb, the elderly did not seem to have different inter-joint coordination variability of the lower limbs compared to the young when the trailing limb was crossing (Fig. 1-2). The trailing toe-clearance and joint kinematic patterns in the sagittal plane were also similar between the elderly and young groups [5]. Therefore, for the elderly, with the same stability of inter-joint coordination, crossing with the trailing limb did not increase the risk of falling when compared to crossings with the leading limb, in agreement with Palta et al. [6].

In conclusion, the elderly were found to cross obstacles with increased leading toe-clearance but unaltered inter-joint coordination pattern. During the leading limb crossing, greater variability of the inter-joint coordination, correlated to the increased toe-clearance, indicates that aging reduces the reliability of the way the lower limb joints are controlled during obstacle-crossing. Variability of the trailing stance knee-ankle coordination may be an important parameter in identifying older people with a higher risk of falling. The elderly did not change the pattern and variability of the inter-joint coordination during the trailing limb crossing possibly because it is relatively easy for the elderly to meet the mechanical demands despite increased age-related organismic constraints.

		Swing limb		Stance limb	
	Height	Hip-Knee	Knee-Ankle	Hip-Knee	Knee-Ankle
Leading limb crossing	10%	0.57 (p=0.016*)	0.57 (p=0.015*)	0.31 (p=0.382)	0.40 (p=0.019*)
	20%	0.58 (p=0.036*)	0.59 (p=0.032*)	0.26 (p=0.345)	0.52 (p=0.008*)
	30%	0.62 (p=0.006*)	0.59 (p=0.011*)	0.19 (p=0.549)	0.54 (p=0.014*)
Trailing limb crossing	10%	0.16 (p=0.905)	0.27 (p=0.514)	0.47 (p=0.137)	0.15 (p=0.465)
	20%	0.08 (p=0.978)	0.18 (p=0.812)	0.47 (p=0.059)	0.43 (p=0.104)
	30%	0.25 (p=0.210)	0.37 (p=0.210)	0.25 (p=0.562)	0.19 (p=0.779)

Table 1 Correlation coefficients (R) between DP values and toe-clearances for all subjects. An asterisk indicates a significant difference.

4、References

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