IN WATER AND ON LAND FORWARD AND BACKWARD SPATIOTEMPORAL GAIT CHARACTERISTICS

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Introduction

Forward and backward walking is a common exercise for rehabilitation due to the major role that locomotion plays in an individual's quality of life [1]. Aquatic exercises are widely used alongside traditional land-based therapy because of the beneficial physical characteristics of water on various body systems [2]. Walking underwater, for instance, impacts the muscular-skeletal system, reducing fatigue and pain and improving the physical recovery rate as well as the joints' range of motion [3]. A recent systematic review [4] pointed out that the use of wearable inertial measurement unit sensors (IMUs) in water for human biomechanical motion analysis is still limited. In particular, no previous studies investigated the kinematic differences between forward and backward walking in water using wearables. Therefore, the aim of this investigation is to explore gait analysis via customized IMUs estimating and comparing forward and backward spatiotemporal gait parameters and gait phases, in and outside water.

Methods

Five healthy female volunteers (24.5 ± 0.6 years old), with no previous history of injuries at the lower limbs, were included. They were asked to walk ten times at their preferred self-selected regular pace forward and backward in a straight line, inside and outside water (swimming pool: 1.20m depth, 33°C, Enjoy Sport center, Cernusco sul Naviglio, Milano, Italy). Two IMUs, developed by Tallinn University of Technology (Tallinn, Estonia) were placed on the instep of both feet using self-adhesive tape. The loggers are small (30x12x9mm) and lightweight (about 7g), causing as little discomfort as possible and not interfering with the subjects' movements. The sensors include an absolute orientation sensor (BMX160, Bosch), sampling at 100Hz, a microcontroller and onboard memory. The devices have been specifically developed for underwater applications and therefore do not require any casing or specific precautions to be employed safely. The first two complete gait cycles of the left and right legs were investigated. Matlab (2022b) was used to define the gait events from the accelerometer data and to estimate the spatiotemporal gait parameters. The stride time is identified as the period between two subsequent homolateral foot strikes (respectively heel or toe strike during forward or backward gait) while the stance and swing components are identified respectively as the portions of the gait cycle in which the foot is in contact with the ground and in which it is undergoing motion.

Results

The results of stride time expressed in seconds and stance and swing components expressed as a percentage of the gait cycle are resumed in Figure 1, for both forward and backward gait on land (brown) and in water (blue). Right and left gait parameters are displayed together after checking the two populations with the two-sample Kolmogorov-Smirnov test to assess whether they come from the same distribution.

Discussion

The stride time underwater is more than doubled for both forward and backward gait, showing a much higher variability and uncertainty. In water, the stride time was observed to considerably decrease between forward and backward gait, with a difference of 0.5s (about 17% of the stride time during forward walking). These results might be related to the higher density of water with respect to air, which creates a safe environment that reduces the fear of falling during backward gait and simultaneously increases the difficulty of moving consistently, increasing the gait variability. Despite the differences in stride time, the partitioning of the gait cycle in stance (about 60%) and swing (about 40%) phases remains invariant for land and underwater environments and for forward and backward gait.

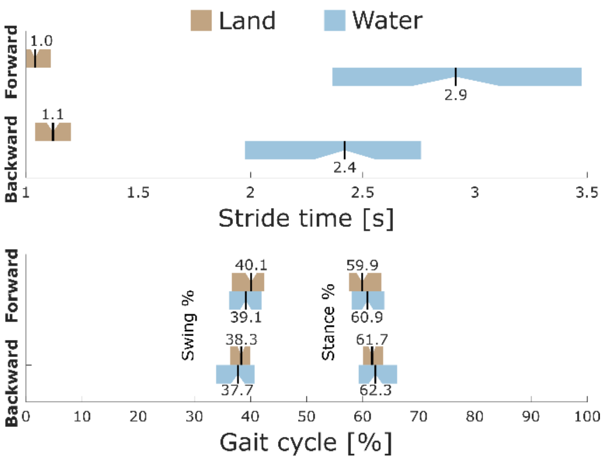

Figure 1: Gait parameters (stride time, stance and swing components of the gait cycle) of forward and backward gait on land (brown)and in water (blue).

References

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