Assessment of Gait Harmony in Older and Young People

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Abstract: Recent studies have found that in normal human walking the *stance* and *swing* phases are approximately in proportion to ϕ, the golden ratio. This could provide an interesting tool in human gait analysis, in diagnosing pathological conditions or in analysing the walking performance of a subject. However, the assessment of gait harmony was provided in previous studies by means of optical systems, which are not ideal for clinicians, because of non-portability, high-costs, and necessity of expert supervisor skills. In addition, the assessment regarded mostly middle-aged or aged people. Differently, this work is based on wearable technology to sense human walking, and reports a comparison between elder and young people. Results demonstrate how elders adopt a walking style which better minimizes the energy expenditure.

1 INTRODUCTION

Human walking is extensively studied in different research fields, such as physiology, computer animation (Multon et al., 1999), control theory, biomechanics (Cappellini et al., 2006; Bauby and Kuo, 2000), and so on. Gait analysis supports medical diagnosis (Jankovic, 2008) and allows developing humanoid robot locomotion (Ames et al., 2012). Nevertheless human walking is still far to be completely understood, and new findings are more than welcome.

Walking is a succeeding of movements, periodically repeated (Figure 1), named gait cycle (Ayyappa, 1997), which can be essentially related to two main phases: a *stance phase* (or, simply, *stance*) and a *swing phase* (or, simply, *swing*). The *stance* is when the foot is in contact with the ground, the *swing* is when the foot in in the air moving forward. During walking one leg is in *stance* and the other leg in *swing*.

The *stance* is, in turn, divided into three phases: hell-strike, foot-flat, foot-off. Analogously, the *swing* consists of: acceleration, mid swing, deceleration.

Recent studies suggested how in normal human gait of healthy adults (49±19yo) the *stance* and *swing* ratio of a gait cycle seems to be close to ϕ, feature named "Gait Harmony" (Iosa et al., 2013), with $\phi \cong$

1.618 being the "golden ratio", an irrational number. This ratio seems to be altered in adults (67.23±10.65yo) suffering from pathological conditions affecting the walking movements, such as Parkinson disease (Iosa et al., 2016b). Morehover the closeness to ϕ was associated to a walking with minimal energy expenditure (Serrao et al., 2017).

All those works were based on measurements made by means of video-capturing and video-motion analisys systems, which are meaningfully considered as a standard-gold, but with the drawbacks to be very expensive, highly technical, non-portable, not-practical for clinical environments or multisite clinical trial equipments. In addition, all those works did not considered very young people, mainly investigating middle-aged or aged people.

Differently, useful objective measures of human walking need to be cost-effective, portable and easy to andle, as in can be by means of wearable electronics (Greene et al., 2015; Hsu et al., 2014; Spain et al., 2012; Solomon et al., 2015; Bonora et al., 2015), and have to take into account a wider age-range, including young people.

Therefore, our work is devoted to consider the evidence of the presence of ϕ, if any, according to measures acquired by means of inertial wearable sensors in healthy people ranging from young to aged.

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