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Original article

Reference database of the gait cycle for young healthy Tunisian adults

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Abstract

Background. – Quantified gait analysis is a rising technology used increasingly to assess motor disorders. Normal reference data are required in order to evaluate patients, but there are no reference data available for the Tunisian healthy population.
Aim. – To assess the features of normal Tunisian gait pattern, and examine the intrinsic reliability of spatio-temporal, kinematic and kinetic parameters within a new specific reference database.
Methods. – Eighteen healthy active-young adults (age: 23.30 ± 2.54 years, height: 1.78 ± 0.04 m and, weight: 70.00 ± 4.80 kg) have participated to five trials of step gait where the dominant lower limb were recorded. Two over the five trials were randomly selected to be further analyzed. Twenty-three spatio-temporal, kinematic and kinetic parameters determined from 3-dimensional gait analysis. The intrinsic reliability was examined for each variable and our results were compared with those available in the literature.
Results. – Twelve over 23 parameters have an excellent intrinsic reliability ($P > 0.05$, ICC > 0.9 and SEM < 5% of the grand mean). There are similarities with other studies ($P < 0.05$) but we noticed the existence of some specificity (the height of hip extension peak and the low cadence of gait) that could characterize the Tunisian population.
Conclusion. – A specific reference database of the gait cycle has been established for healthy Tunisian active-young adults and excellent inter-trial reliability may be observed for different variables.

1. Introduction

The quantified gait analysis aims to evaluate the mechanics of walking, and to facilitate the identification of deviations from normal movement patterns. The underlying cause of such anomalies and their functional consequences can then be determined to deliver treatment recommendations. The objective quantification of the biomechanical parameters patterns, allowing a more accurate assessment of gait deviations than the visual assessment [1], has improved our understanding of normal and pathological gaits and the effectiveness of specific treatment modalities. The quantified gait analysis is widely accepted as an excellent research tool, which provides a strong support to refine the causes of gait disturbances caused by different pathologies. Consequently, gait analysis can lead to savings for the healthcare and long-term improvement in functional status of the patients [2].

Despite the growing number of laboratories involved in gait analysis, consistent information on the reproducibility of gait kinetic and kinematic parameters is limited. Nevertheless, reproducibility and validity of gait measurements should be known to be used appropriately. McGinley et al. [3] provide a systematic review of studies assessing the measurement uncertainties related to operators, protocols and motion analysis systems, and propose a qualitative assessment of the reliability of three-dimensional kinematic gait data. Besides, other biasing factors such as anthropometric measurements, changes in

Abbreviations: Abd/Add, abduction/adduction; Flex/Ext, flexion/extension; GRF, ground reaction force; ICC, inter-class correlation; Int/Ext, internal/external; ROM, Range of motion; SEM, standard error of measurement; 3-D, three dimensions.

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walking speed, errors in data processing or measuring equipment may also contribute to variation of the data [4]. Other authors have gone further by analyzing the uncertainty between laboratories [5].

The variability between trials may be considered as "intrinsic variation", and reflects the inherent intra and inter-subject variation in healthy individuals or those with pathology [6]. These intrinsic variations cannot be reduced, but they provide a basic indication of the variation independent of sources of error. The data of adult gait are generally found less variable than those of children and, those of young children are also more variable than those of older children [7]. Moreover, children with cerebral palsy show a greater variability for kinematic parameters of gait than the healthy children [8]. Then, gait data reliability is intrinsically linked to the variability within the studied group [3]. In addition, most of the gait analysis laboratories are equipped with one or two force platforms, a single step can then be collected by trial. Consequently, several tests must be performed to obtain a sufficient number of steps. This could induce a lack of reproducibility and walking speed can vary from a test to another.

Several researchers established that, in order to better understand the behavior of a subject, the results of the latter should be compared to a given database of non-pathological subject [4,9,10]. The most frequently studied differences are those associated with age. A normative database of gait parameters is so desirable; it must consider the wide spectrum of that which is considered normal, including the differences not only in sex and age, but also among people in different geographical locations and cultural backgrounds [11]. Consequently, the reference population should be composed of individuals who are as close as possible to the analyzed patient. Moreover, each laboratory must have its own database since the data depend on the protocol and equipment used, the lab environment, the data processing and the therapists [5]. This study aims to explore whether there are different features for the considered sample, and to examine the intrinsic reproducibility of spatio-temporal, kinematic and kinetic parameters within this database.

2. Material and methods

2.1. Subjects

Eighteen healthy men participated in this investigation. The mean (SD) of age, height, body mass and BMI are respectively: 23.30 (2.54) years, 1.78 (0.04) m, 70 (4.80) kg and 22.08 (1.07) kg.m^{-2}. The participants were physical education students. All of them were physically active as they performed more than 4.5 (range: 4.5–6) exercise sessions per week (both endurance and strength training), but none of them performed exercise on an elite level. All were volunteers and had given their informed consent for their participation. The subjects have been excluded if they had a history of fracture or surgery to the lower limbs, a history of multiple lateral sprains ankle, or symptoms of acute injury of the lower limbs on the day of testing.

2.2. Equipment used

The laboratory uses a Motion Analysis® system, consisting of six Eagle-4 cameras, coupled with a force platform AMTI® embedded in the ground. Both devices collected data synchronously at a frame rate of 100 Hz.

2.3. Placement of markers on the subject

The Helen Hayes marker-set [12] was used to model the lower limb in four rigid segments (foot, leg, thigh and pelvis). In our case, three evaluators participated in this study: two expert assessors and a novice assessor who had a minimum of training for fixing markers.

2.4. Experimental testing

Before starting the data collect, the subjects become accustomed to the 10 m length walking path for about 10 min to find a natural walk.

2.4.1. Static registration

The subject equipped with markers is first recorded in a static standing position on the force platform. This record has several objectives: it serves as a reference for the expression of kinematic results and the net joint forces and moments (expressed in terms of the subject's weight, measured by the force platform).

2.4.2. Gait recording

The subjects were instructed to walk at a comfortable speed ("as if you're on the street"). The subject then started walking before entering the field of cameras and continued after so that the steps of acceleration and deceleration were outside the analyzed field. In order that the movement was as natural as possible, the subject kept his eyes fixed on the wall in front of him, and his starting position was adjusted forward or backward to increase the probability that the stance phase actually takes place on the force platform. The trial was retained only if the stance phase of the dominant lower limb was correctly centered on the force platform. Five trials were recorded for the dominant lower limb, and two of them were randomly selected to be further analyzed. It has to be noticed that all subjects were wearing standard sportswear provided by the experimenter to cancel any influence of clothing and footwear.

2.4.3. Data process

The 3-D trajectories of markers were computed using Cortex 1.1 software and low-pass filtered (Butterworth order 4, cutoff frequency of 5 Hz) to eliminate the high frequency noise. The algorithm of segments solidification was then applied to correct some of the soft tissue artifacts [13].

2.5. Processing of the experimental data

The segment coordinate systems were those previously defined, consistent with international recommendations [14]. Joint angles were computed using joint coordinate systems. Net joint forces and moments were then computed using an