DETECTION OF BIOMECHANICAL ADAPTATION IN TREADMILL RUNNING

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This study aims to propose a procedure for the detection of adaptation to treadmill running regarding biomechanical variables. Male novices in treadmill running (n=12) participated in one session of treadmill running while 3D motion analysis was executed. Statistical and analytical analyses supplemented with optimization algorithms within the proposed approach were applied to 14 common biomechanical variables. Overall, a low number of adapting data set was found. Even though adaptation has possibly been overrated, these processes have to be considered if study outcome might be influenced. However, due to unsystematic occurrence of adaptation, familiarization to treadmill condition cannot be generalized within a test group.

KEY WORDS: familiarization, running environment, individual analysis.

INTRODUCTION: Standardized settings with regard to running speed, slope or climatologic aspects are often required for biomechanical analyses (Garcia-Perez, Perez-Soriano, Llana, Martinez-Nova, & Sanchez-Zuriaga, 2013; Lavcanska, Taylor, & Schache, 2005). Treadmills provide control of the testing environment and allow for repeatable and reliable measurements. Surveys are therefore often conducted in favour of the treadmill condition, despite potential differences to overground running (Fellin, Manal, & Davis, 2010; Nigg, De Boer, & Fisher, 1995). However, adaptation due to familiarization to the device has to be considered and can occur as a direct response to altered conditions or an active process over time (Hardin, van den Bogert, & Hamill, 2004). Insufficient consideration of adaptation to the treadmill environment might affect biomechanical analyses. Consequently no separation of contributors to differences in biomechanical tests is possible. Group analyses of adaptation, providing times until a stable running pattern is reached, have been conducted for treadmill walking and running (Lavcanska et al., 2005; Matsas, Taylor, & McBurney, 2000; Schieb, 1986). Familiarization times of six minutes were determined in the study of Lavcanska et al. (2005): Data of discrete variables collected at described measurement times within ten minutes of treadmill running served as a basis for evaluation of stabilization time. Analyses of variance followed by post hoc comparisons, correlation analyses and differences between consecutive measurement times were implemented. Stabilization time was defined (i) when no significant post hoc comparisons were determined, (ii) differences between consecutive measurement times were minimal and (iii) the investigated variables were most reliable. Consideration of stabilization time has been seen as an important aspect. Nevertheless, within this method of group analysis, participant-specific characteristics of prolonged running patterns are barely considered. It remains unknown, how individual characteristics contribute to these analyses of stabilization time. As a fragmentation of the existing method described by Lavcanska et al. (2005), the aim of this study was to propose a new approach for the detection of adaptation in individual data sets conducted during treadmill running checking for the relevance of adaptation in novice treadmill runners related to practice and distribution of adaptation in participants and variables.

METHODS: Male experienced runners (n=12, 25±3 y, 181±5 cm, 78±7 kg) being novices in treadmill running gave written informed consent for participation in this study with approval by the ethics committee of the University of Salzburg. The participants performed a treadmill running session with 3D motion analyses (12 camera system, 42 reflective skin markers, Vicon, Oxford Metrics Ltd, Oxford, UK; 250 Hz). Within 15 minutes of running, data from five consecutive strides were collected at the beginning of each minute. Gait events were detected based on the markers on the heel and tip (Maiwald, Sterzing, Mayer, & Milani, 2009). Common variables in biomechanical analyses (Table 1) were extracted from the data using Visual 3D (Version 5, C-Motion Inc., Rockville, MD, USA) and Matlab (R2015b, Mathworks Inc., Natick, MA, USA). Joint centers for calculation of angular values were derived from geometric definition techniques. Data sets were formed for each variable per participant from the 15 measurement times consisting of five strides each. A total of 168 data sets was checked for adaptation by the following developed procedure: First, each individual data set was tested for potential changes within the data set (analysis of variance), then tested for mechanisms (characteristics of changes) as well as rechecked for relevance of changes and further assigned to one of four possible classes: STABLE (no significant fluctuation at all), CONTINUOUS ADAPTATION ((i) the average of one minute in z-transformed data has to exceed a defined value, (ii) a power function is fitted to the data and (iii) the root mean square error between the fit and the z-transformed data must be below a defined value), SUDDEN ADAPTATION (difference between averages of consecutive measurement times in z-transformed data exceeds a defined value and no crossing of data occurs before and after the leap), NON-DIRECTIONAL FLUCTUATION (significant changes occur without assignment to defined adaptation mechanisms). Values within criteria for CONTINUOUS ADAPTATION and SUDDEN ADAPTATION were determined by an optimization algorithm extracting a combination of possible parameters receiving maximum amount of adaptation data sets. Rechecks for relevance using expectable variances (Barrett, Noordegraaf, & Morrison, 2008; Brisswalter & Mottet, 1996; Dingwell, Cusumano, Cavanagh, & Sternad, 2001; Meardon, Hamill, & Derrick, 2011; Nakayama, Kudo, & Ohtsuki, 2010) were applied before classification in order to assign data sets with low standard deviation (angular data) or coefficient of variation (spatiotemporal data) to stable class.

Table 1
Selected biomechanical variables

variable	assigned acronym
foot to ground angle	V1
ankle dorsiflexion at initial contact	V2
knee flexion at initial contact	V3
hip flexion at initial contact	V4
ankle $dorsiflexion_{max}$ (stance phase)	V5
ankle $plantarflexion_{max}$	V6
knee $flexion_{max}$ (stance phase)	V7
knee $flexion_{max}$ (swing phase)	V8
hip $flexion_{max}$	V9
hip $extension_{max}$	V10
step frequency	V11
stride frequency	V12
stance time	V13
swing time	V14

RESULTS: Overall, 6.0% of the data sets were classified as adaptation (CONTINUOUS ADAPTATION; no SUDDEN ADAPTATION data set was found within the 168 data sets), 12.5% as NON-DIRECTIONAL FLUCTUATION and 81.5% as STABLE data sets. Exemplary data sets assigned to CONTINUOUS ADAPTATION are depicted in Figure 1 (standardized, z-transformed data). Individual analysis of data sets revealed participant-specific as well as variable-specific characteristics in terms of distribution among classes (Table 2). Six out of fourteen variables were STABLE for all participants. The remaining eight variables show STABLE data sets for five to eleven participants. For no variable, more than seven participants show adapting or fluctuating data sets. Participant-specific analysis reveals STABLE data sets ranging from eight to fourteen over the fourteen variables.

DISCUSSION: This study aimed to develop a procedure for individual detection of adaptation in biomechanical data sets gathered from treadmill running. Participant- and variable-specific analyses reveal unsystematic occurrence of adaptation. Overall, a low number of adaptation data set was found and the question of relevance of adaptation arises. Furthermore, within approximately half of the dependent variables in the study of Lavcanska et al. (2005), no significant differences could be detected based on the analyses of variance and therefore no adaptation within those variables could be assumed. However, as adaptation can substantially influence study outcome, this still remains a topic worth of consideration. In addition to group analyses of stabilization time, the proposed approach was found to be an adequate tool for the initial detection of adaptation as specific characteristics are considered.

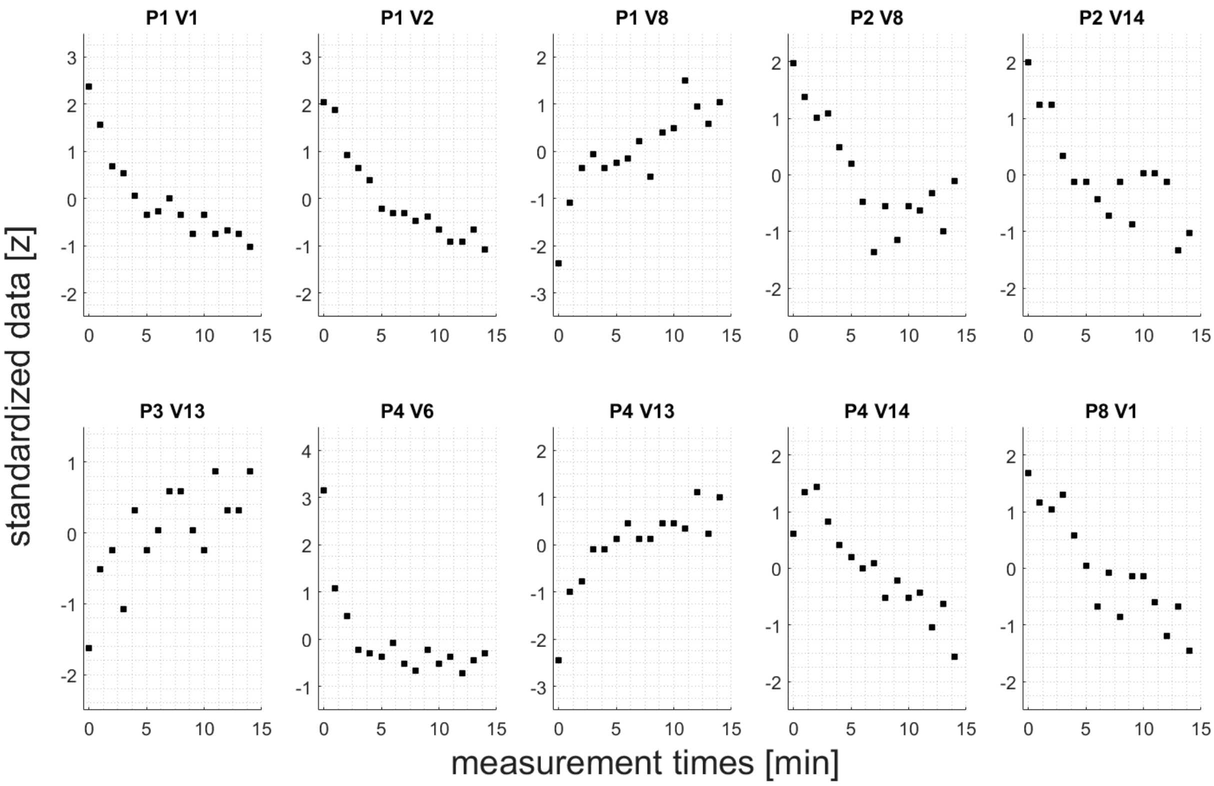

Figure 1: standardized data of data sets classified as continuous adaptation

Table 2
Classification of individual data sets (black = CONTINUOUS ADAPTATION, grey = NON-DIRECTIONAL FLUCTUATION, white = STABLE); numbers of STABLE data sets within participants and variables are given in parentheses; no SUDDEN ADAPTATION occurred

participants / variables	P1 (10)	P2 (10)	P3 (10)	P4 (8)	P5 (14)	P6 (13)	P7 (10)	P8 (11)	P9 (13)	P10 (12)	P11 (13)	P12 (13)
V1 (7)												
V2 (9)												
V3 (11)												
V4 (12)												
V5 (12)												
V6 (10)												
V7 (12)												
V8 (6)												
V9 (10)												
V10 (12)												
V11 (12)												
V12 (12)												
V13 (7)												
V14 (5)												

CONCLUSION: As specific characteristics have to be considered with regard to different variables and participants, generalized familiarization times revealed from group analyses might not serve as elimination of adaptation aspects due to altered conditions in biomechanical testing. The amount of adaptation data sets indicates that adaptation in terms of familiarization to treadmill condition might have been overrated as the majority of data sets show stable patterns. Nevertheless, if familiarization to the device might influence study outcome, data received from treadmill conditions require individual adaptation checks. Furthermore, stabilization times for the adaptation data sets would have to be evaluated individually. In general, for those data sets an adequate time of treadmill running for completed adaptation without fatigue has to be chosen. Giving recommendations for eliminating possible influence of familiarization to treadmill condition in biomechanical testing is therefore a challenging task without preceding individual analysis of adaptation and subsequent stabilization time.

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