PRONATION VELOCITY VALUES OF RUNNING SHOES ARE DEPENDENT ON THE MATHEMATICAL ROUTINES APPLIED DURING DATA POST PROCESSING

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INTRODUCTION

Pronation velocity (PV) is used to assess running shoe stability properties and is discussed in relation to running injuries [2]. However, the methods to determine PV vary between research groups. Nigg (1986) recommended to measure an average PV for the first 10th of ground contact (GC) [3], Cavanagh (1990) suggested to evaluate a maximum PV [1]. In the majority of todays papers the used calculation algorithms of PV are not presented. This paper compares different mathematical determination methods of PV for ten different running shoe models to find the appropriate mathematical routine. The results of this study may contribute to the discussion of the influence of mathematical methods on biomechanical outcomes.

METHODS

A biomechanical data set of twenty male, injury-free, recreational heel-to-toe runners (age: 26.4 ± 2.5 yrs, height: 176.4 ± 4.7 cm, weight: 73.1 ± 6.4 kg) running in ten different running shoes was used for this analysis. Subjects performed five repetitive running trials across a force plate (Kistler 9287BA) at a speed of 3.5 ± 0.1 m/s. Frontal plane rearfoot angle (RA) was recorded using an electrogoniometer [4] at 1000 Hz and low-pass-filtered at 50 Hz. The discrete parameters maximum supination angle (RA_{min}) and maximum pronation angle (RA_{max}) were determined during GC. Subsequently, three different algorithms were used to calculate PV:

$$APV_0 = \frac{RA_{\max} - RA_{\min}}{t_{n-1} - t_0}$$

– average pronation velocity between RA_{min} and RA_{max}

$$APV_{10th} = \frac{RA_{10th} - RA_{\min}}{t_{10th} - t_0}$$

– average pronation velocity during first 10th of foot contact

$$MPV = \max_{t_i}\left(\frac{RA_{t_{i+1}} - RA_{t_i}}{t_{i+1} - t_i}\right)$$

– maximum pronation velocity

t_i – equidistant time steps between t_0 (time of RA_{min}) and t_{n-1} (time of RA_{max})

t_{10th} – time of rearfoot angle at first 10th of foot contact

PV differences between shoes were determined with the nonparametric Friedman test separately for each algorithm. Based on this test comparisons of the variation of the three different mathematical algorithms were performed. Comparisons included the analysis of shoe orders. In a further step the MPV algorithm was applied to new time lines which were generated by dividing the interval $[t_0; t_{n-1}]$ into smaller intervals with length of 2 to 10 ms (algorithms labeled with MPV_k, lag k=2,…,10). Rank comparisons were used for all k-values in order to assess equivalence of the outcome variables MPV_k.

RESULTS AND DISCUSSION

Friedman tests for differences between shoes were significant ($p<0.001$) for all algorithms (APV_0, APV_{10th}, MPV). However, rank orders of shoes differ between all methods applied (Table 1). The ranks of MPV_k for all k were identical. Therefore, it is permitted to consider the algorithms MPV_k equal for all k. Figure 1 emphasizes that the differences ($MPV - MPV_k$) increases with larger lags while all MPV_k algorithms generated the same rank order.

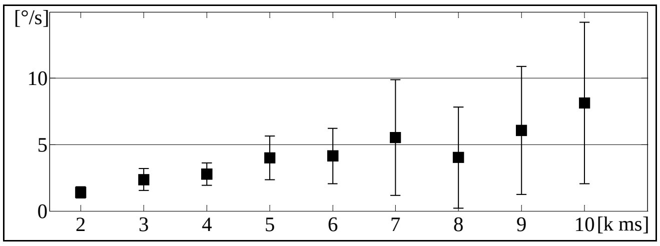

Figure 1: Differences $MPV - MPV_k$ for different lags k

CONCLUSIONS

To ensure comparability and traceability of biomechanical research results and outcomes it is necessary to state the algorithms used. Mathematically it is recommended to use MPV because of the independence of RA_{min} and RA_{max}. A biomechanical suggestion has to be elaborated with further studies. Beyond this, the influence of mathematical routines on kinematic and kinetic parameters should be analyzed.

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Table 1: Rank orders of various shoes for the applied algorithms (mean ± standard deviation (rank))

Shoes	1	2	3	4	5	6	7	8	9	10
MPV (°/s)	348 ± 90 (1)	377 ± 151 (2)	392 ± 106 (3)	399 ± 103 (4)	399 ± 109 (5)	423 ± 125 (6)	434 ± 146 (7)	455 ± 110 (8)	475 ± 106 (9)	530 ± 153 (10)
APV_0 (°/s)	127 ± 44 (2)	121 ± 54 (1)	151 ± 53 (5)	140 ± 51 (3)	172 ± 62 (7)	148 ± 65 (4)	166 ± 74 (6)	188 ± 61 (9)	246 ± 56 (10)	184 ± 103 (8)
APV_{10th} (°/s)	119 ± 77 (1)	185 ± 78 (3)	237 ± 79 (6)	175 ± 77 (2)	224 ± 85 (4)	234 ± 73 (5)	241 ± 66 (7)	266 ± 68 (8)	278 ± 71 (9)	297 ± 83 (10)