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Short Communication

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Abstract

The purpose of this investigation was to examine if baseline measures are altered between conditions in biomechanical studies and to determine the need for baseline measurements in biomechanics. Ten runners were asked to run at varying speeds and obstacle heights. Baseline measures were acquired between all conditions. Right lower extremity kinematic and kinetic data were collected for all baseline trials and evaluated by both a group and a single subject analysis. The group analysis revealed significant differences between baselines only for the obstacle perturbation. The single subject analysis indicated that baseline measures are altered in a greater degree for kinematics than kinetics. These findings suggested that baseline measures are altered between conditions in biomechanical studies, and they should be used when a repeated measures or a single subject experimental design is being utilized.

Keywords: biomechanical experimental designs, baseline measures, obstacle, speed, locomotion.

Introduction

Paragraph 1. Often biomechanists measure the average performance within a group of individuals and generalize this information to a larger population without regard to how any given individual performed. For example, biomechanists have attempted to establish the norm for the average runner. Measuring the average performance within a group of individuals provides information on the distribution of behavior within the group. Given the methods by which individuals were selected to be in the group, can provide probability statements about the average performance within the larger population represented by that group. However, such designs do not provide information about how any given individual performed or might perform in the future (Bates, 1996; Dufek, Bates, Stergiou, James, 1995a). This observation coupled with the need in medicine to evaluate each patient and thus provide an individual with a specific program for injury prevention or rehabilitation, support the use of Single Subject (SS) designs. The question of generalizability of the effect for other subjects in the population can then be approached by succeeding investigations using additional subjects.

Paragraph 2. Although the usage and need for SS designs in biomechanical studies has been demonstrated by Bates and colleagues (Dufek et al., 1991, 1995b; Bates, 1996), their work has not addressed the topic of baseline measures. The evaluation and usage of baseline data between conditions where an independent variable (speed, footwear, obstacle height, etc.) is manipulated can be critical to the evaluation of treatment effects (Heward, 1987; Matyas & Greenwood, 1990). Thus, the primary purpose for establishing baselines is to use the subject’s performance in the absence of the independent variable as an objective basis for evaluating the effects of the independent variable (Heward, 1987; Cooper et al, 1987). In the event that baseline measures are altered by multiple treatments, the results may need to be normalized using the baseline data. Thus, a multiple baseline design allows for the examination of the true treatment effects. In fact, a SS design is not the only experimental method that can benefit from the usage of baselines. This is also the case in any repeated measures type of experimental design (Heward, 1987; Kratochwill, 1992). Baseline adjustments have been used in behavioral studies to assess and account for the cumulative effects of treatment (Gregory, 2002; Schlosser et al, 1998). However, an extensive review of the available literature showed that within the biomechanics discipline baseline measurements have not been used. Therefore, the purpose of our investigation is to examine if baseline measures are altered between conditions in biomechanical studies and to determine the need for baseline measures in biomechanics.

Methods

Paragraph 3. Ten, male (N = 6) and female (N = 4), runners who had been running a minimum of 10 miles per week for at least one year (mean age: 25.9 yr; mean body mass: 73.45 kg; mean height: 177 cm) ran under two different experimental settings, obstacle heights and speed changes. Before testing, each subject read and signed an informed consent form consistent according to university policy.

Paragraph 4. On both obstacle and speed experimental settings, the subjects were given time to adjust to the experimental set up. During warm up a comfortable self-selected pace (±5%) was recorded for each participant. The running speed was monitored over a 3-meter interval using a photoelectronic timing system (Lafayette Performance

Pack model 63520, Lafayette, IN). Following warm up, a foot placement marker was used before the timed interval to allow for a normal right foot contact on the force platform. This was done to insure stride length was not changed between trials. During all trials right lower extremity, sagittal view (200 Hz), kinematic data was collected using a NEC high-speed video camera interfaced to a real time automated video-based tracking system (Motion Analysis Corporation, Santa Rosa, CA). Reflective markers were placed on the subject's right lower extremity to allow for path tracking. Specifically, the sagittal view markers were placed as follows: a) lateral malleolus, b) knee joint center, and c) greater trochanter. An Advanced Medical Technologies Inc. (AMTI Model OR6-5-1, Arlington, VA) force platform (1000 Hz) was used to collect ground reaction forces.

Paragraph 5. For the speed experimental setting (Figure 1A), the subjects ran at four different speeds: their comfortable self-selected pace, 10% faster, 10% slower, and 20% faster. For the obstacle experimental setting (Figure 1B), the subjects ran at their previously established self-selected pace over obstacles of three different heights: 5%, 10% and 15% of their standing height. The obstacles were placed directly before the force platform so the subject had to clear the obstacle with the right leg and land on the force platform. The subjects were instructed to run over the obstacles and avoid jumping over them, ensuring a normal heel-toe running pattern. Each speed and obstacle condition consisted of 10 trials, and the order of presentation of the conditions was randomized. Between conditions, 10 trials of unperturbed running were collected as baselines for both settings (Figure 1). Each trial consisted of a run of approximately forty meters. Data transfer from the cameras to the computer and the qualitative inspection of the force curves allowed for a 1 -1.5 minute inter-trial rest interval. All subjects were able to continue this procedure with no fatigue effects while seventy successful data trials per setting were obtained. The above protocol is presented in detail in Stergiou et al. (1999). One kinetic variable (vertical Ground Reaction Impact Force; GRIF) and one kinematic (Minimum absolute Knee Angle during stance; MKA) were identified for all baseline trials. These two variables were selected because they are widely used in the biomechanical literature. Means for these variables were generated for each baseline (Figure 1). Subject means were calculated across trials for each subject, and group means were calculated across subjects. The baseline group means for GRIF and MKA and from each experimental setting (speed and obstacle) were analyzed using ANOVA with repeated measures ($p<0.05$) with a Tukey test as post-hoc. The baseline subject means for GRIF and MKA and from each setting were also analyzed with a Single Subject statistical procedure (Model Statistic; Bates, 1996). In this latter procedure and for each subject, the difference between two baseline subject means is compared with the product of the mean standard deviation and a criterion test statistic based on number of trials (Bates et al., 2004).

Results

Paragraph 6. The ANOVA group analysis revealed mixed results. Specifically, the results indicated no significant differences between the baseline group means for both dependent variables in the speed setting (Table 1). However, significant differences were found in both variables for the obstacle setting indicating an effect on baseline measures. Post-hoc analysis showed significant differences between the first and the last two baselines in the obstacle setting (Table 1). The location of these differences was the same for both the kinematic and the kinetic variable.

Paragraph 7. The Single Subject analysis revealed significant differences not previously detected by the group analysis. Specifically, the Single Subject comparisons for the kinematic variable showed that 15% and 30% of all baseline subject means comparisons were significantly different for the speed and the obstacle settings, respectively. For the kinetic variable, the results were 13.3% for the speed setting and 18.3% for the obstacle setting. The use of Single Subject analysis revealed further evidence that baseline measures are altered.

Discussion

Paragraph 8. The goal of this investigation was to examine if baseline measures are altered between conditions in biomechanical studies and to determine the need for baseline measures in biomechanics. A kinetic variable (GRIF) and a kinematic variable (MKA) were chosen as two representative parameters in the biomechanical literature. Baseline group means indicated no significant differences in the speed setting for either kinematic or kinetic variables. However, the obstacle setting did show significant differences in both variables. In fact, significant differences were found between the first baseline and last two for MKA and GRIF (Table 1), revealing a decreasing trend for both dependent variables. This suggests an accumulative treatment effect (the varying obstacle height) that would further support the usage of baselines in repeated measures designs in biomechanics. The fact that baselines were influenced differently in the two independent variables (speed and obstacle) maybe due to the biomechanical differences between changing running speed and running over obstacles. Experimental studies (Farley et al. 1993) showed that leg compliance is not much influenced by running speed (especially if the speed range is quite small, as the case with the current study). To cope with obstacles, in contrast, larger flight phases could be achieved by a more compliant leg operation during stance (Farley and Gonzalez, 1996) as indicated by an increased amount of leg shortening (larger knee flexion).

Paragraph 9. The results of the Single Subject comparisons indicated significant differences for both dependent variables (GRIF and MKA) and settings (speed and obstacle). Obstacle perturbation had a larger treatment effect than speed. This was evident by the larger number of baseline subject means comparisons being significantly different (Table 2). Furthermore, the Single Subject analysis showed that this effect was more likely to occur for the kinematic variable (Table 2). Single Subject analysis revealed differences that may have been ignored without its use. Previously, in the group analysis, significant differences were not found in the speed setting. With the use of Single Subject analysis such differences became evident. These findings further support that baselines are altered between treatments and there is a need for baseline measurements in biomechanics.

Paragraph 10. In summary, when a repeated measures design is being used in biomechanical studies, baseline measures should be incorporated. This should be the case in both group and Single Subject designs and especially in designs when kinematics parameters are used as dependent variables. The present study found that only the obstacle heights during locomotion could generate a larger treatment effect, which warrants the need for addressing the effects of other perturbations on baseline measurements in future studies. Furthermore, future studies should also examine additional dependent variables besides the two used in this study (MKA and GRIF). In conclusion, these findings suggest that baseline measures are altered between conditions and they should be used in biomechanical studies, when a repeated measures or a single subject experimental design is being utilized.

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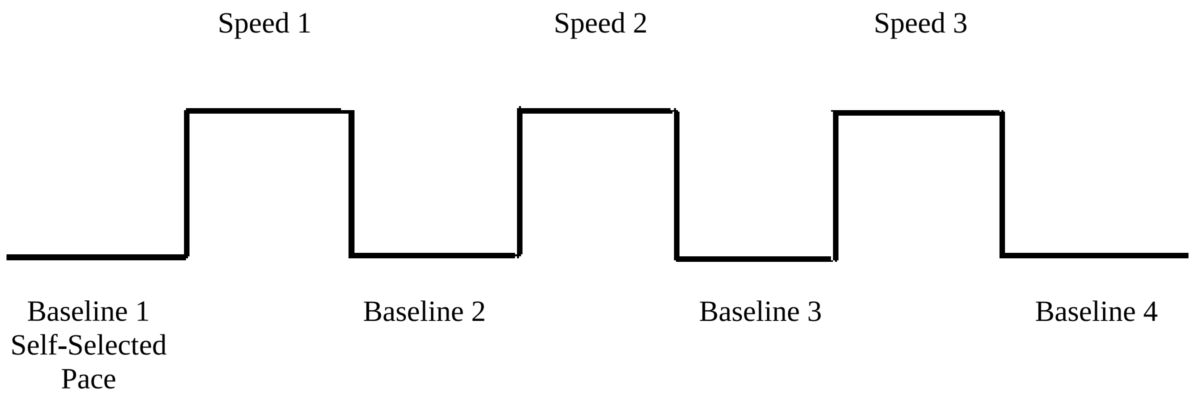
Figure Captions

Figure 1. The experimental protocol used in the Speed (A) and the Obstacle (B) experimental settings. Each baseline consisted of 10 trials of unperturbed running. Each experimental condition (obstacle and speed) consisted of 10 trials. The total number of trials for each setting was 70 trials.

Figure 1

A.


Speed 1
Speed 2
Speed 3
Baseline 1
Self-Selected
Pace
Baseline 2
Baseline 3
Baseline 4

B.

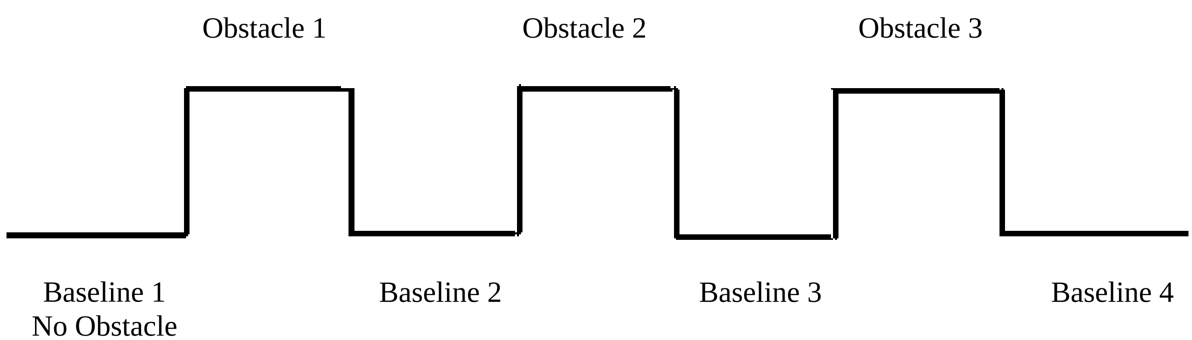

Obstacle 1
Obstacle 2
Obstacle 3
Baseline 1
No Obstacle
Baseline 2
Baseline 3
Baseline 4

Table 1

Table 1: Baseline group means and standard deviations evaluated with superscripts indicating post-hoc significant differences ($p<0.05$). Note that post-hoc comparisons revealed significant differences in the obstacle setting between the first and third baselines, as well as, between the first and fourth.

	Speed		Obstacle	
	MKA (deg)	**GRIF (N)**	**MKA (deg)**	**GRIF (N)**
Baseline 1:	138.6±2.8	1.756±0.4	139.95±2.9[base3, base4]	1.813±0.3[base3, base4]
Baseline 2:	138.2±2.7	1.767±0.4	138.94±2.8	1.745±0.3
Baseline 3:	137.9±2.9	1.713±0.3	138.82±2.8	1.709±0.3
Baseline 4:	138.3±2.8	1.749±0.3	138.75±2.8	1.703±0.3

Table 2

Table 2: Single Subject results presented as percentages of baseline subject means comparisons that were found significantly different ($p<0.05$). Note that a larger percentage of baseline subject means comparisons were found significant in the obstacle setting (5% GRIF more than the speed setting) and the effect was even larger for the kinematic variable (15% MKA than the speed setting).

	Speed		**Obstacle**	
	MKA	**GRIF**	**MKA**	**GRIF**
Percentage	15%	13.30%	30%	18.30%