THE POTENTIAL EFFECT OF MINI-TRAMPOLINE STIFFNESS ON TAKE-OFF BEHAVIOUR OF GYMNASTS – A METHODOLOGICAL STUDY

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The purpose of this study was to compare two mini-trampolines with different spring constant in regard to their effect on take-off mechanics. It was expected that the softer (36 springs) trampoline would lead to a longer contact time and a higher take-off impulse. To assess reaction forces during jumps a flexible force insole was used simultaneously with the measurement of run-in velocity by timing gates. Results showed no significant differences in contact mechanics or contact time indicating that the difference between these two trampolines is only marginal. Therefore, this study provides mainly a novel measurement approach to assess the effect of equipment changes in trampolining. Future studies are warranted to assess the athlete-equipment interaction in greater detail.

KEY WORDS: gymnastics; trampoline; hardness; vaulting; momentum

INTRODUCTION: Trampoline vaulting has gained attention as a part of novel gymnastic disciplines such as team gymnastics and synchronized mini-trampolining as it appears novel and exciting to spectators. Moreover, the mini-trampoline has long been used in teaching and training of gymnastics and therefore deserves attention from a sports equipment point of view. A trampoline vault generally consists of five phases, the run-up, in-jump, take-off contact, flight and landing phase (Hansen et al., 2011). The target for a gymnast in a trampoline hop is to achieve a high centre of gravity (CoG) lift to allow for the execution of difficult exercises. During learning, a higher CoG elevation results in longer air time to practice new movement sequences (Bjørn, 1994). The sport equipment industry offers different trampolines for training and competition to improve air time and flight height but also to provide optimum characteristics for different groups of gymnasts, considering age (body mass) and skill level. No scientific investigations have been published to compare the biomechanical effects of different trampolines.
The purpose of this study was to investigate the effect of altered trampoline stiffness, by comparing a trampoline with 36 and 40 springs, on jump-off characteristics in a group of elite gymnasts. It was hypothesized that a softer trampoline would allow for a longer contact time and higher momentum generation during take-off.

METHODS: The subjects (n = 8) were all men aged 21.2±4.2 years, with a body mass of 78.8±22.8 kg and a height of 181.8±10.8 cm. A skill criterion was that these athletes were able to perform a double somersault with a half turn as a routine jump. All subjects had signed the declaration of consent about participation in the trial. The experiment was set up as a counterbalanced experimental design where two equally sized subgroups performed experimental jumps in reversed order.
A Dorado (No. 40, PE Redskaber, Denmark) and a Dorado (No .36) trampoline were used for this experiment. The trampolines are of the same construction containing 40 springs (T40) of or 36 springs to generate a softer trampoline (T36). Approach velocity was measured using a pair of timing gates (Brower Timing Systems, USA) with the closest set up 1 m in front of the trampoline at a distance of 5 m between the timing gates. The total run-up distance was about 20 m. To measure the contact forces under the feet of the athletes, a pair of force sensors equipped with a Bluetooth wireless interface (Pedoped, Novel GmbH, Germany) was worn within gymnastics shoes (Pro Specs shoe with laces) to secure the positioning of the insoles. An iPod (Apple, USA) was used to connect to the insoles and recorded forces from both insoles at a sample rate of 100 Hz.

The tests were conducted in a gymnasium with gymnastic spring equipment. The experiment was performed on two subjects at a time due to material limitations. In the period where the volunteers did not cooperate in the study they participated in their own training. It was made sure that a sufficient warm-up was performed including the execution of the test jump. Before the start of the experiment, all subjects were measured and weighed. Insoles were calibrated according to the manufacturer's instructions by a static reference measurement on each leg separately. This was repeated prior to each jump to compensate for a possible shift of the insole in the shoe as verified in pilot tests. In each test jump the subjects were instructed to carry out a double closure somersault half-turn as in a performance situation. This task is rated at a difficulty level of 0.65 according Team-Gyms Assessment Regulations (GymDanmark, 2015).
Run-up velocities were protocolled after each jump, and force data were analysed off-line in Excel (Microsoft Office, USA). The forces of both insoles were summed and the initial contact and take-off instances with the trampoline cloth determined when the force was greater than 20 N. The force curve of the cloth contact was integrated using the trapezoid formula.
Data were statistically compared using a t-test which was carried out in Excel. Results are given as mean values ± standard deviation.

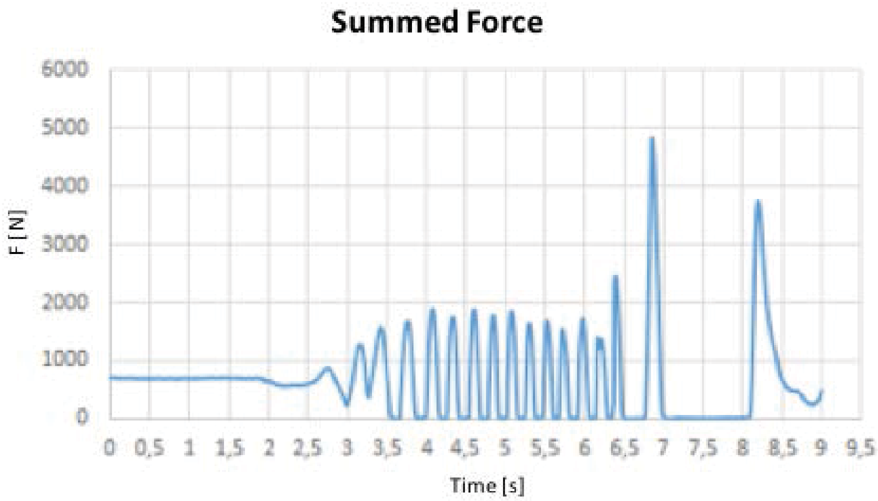

Figure 1: Example of force recording from pedoped insoles (sum of both insoles).

RESULTS: The run-in velocity was not different between the two trampolines. The calculations based on the force recordings revealed the parameters presented in Table 1. No statistically significant differences were found. In fact, there was not even a trend towards a difference in contact time or impulse as it was hypothesized in the purpose of the study.

Table 1
Results for the two trampolines.

Parameter	T36	T40	Cohen's d	Sig.
Run-in velocity [m/s]	7.28±0.35	7.32±0.39	0.11	-
Contact time [s]	0.20±0.01	0.21±0.01	0.44	-
Peak Force [N]	4932±145	4888±198	0.17	-
Impulse [Ns]	527.3±111.0	522.3±123.0	0.05	-
Effective jump height	2.19±0.29	2.16±0.32	0.07	-

DISCUSSION: In this study a novel approach of assessing contact mechanics during gymnastic jumps from a mini-trampoline was presented. Given the result, that there is no deviation in contact time, run-in velocity and momentum between trampolines, the conclusion is that the choice of trampoline with typically used variations in stiffness does not affect jump execution. This is opposed to the experience of the users who in fact apply such different trampolines during training to modify the jump-off characteristics.

In regard to the current study it needs to be noted that a comparably difficult element was chosen to pose a certain demand on the athletes prompting for a large effort during take-off. However, this element was not marking the maximum performance level of each gymnast. It may therefore be that an athlete is able to adjust his/her leg stiffness in a way that the momentum generated from the trampoline remains similar in anticipation of the selected jump. Different instructions, e.g., to ask the athlete to execute a simpler jump but aiming at maximum flight time (height) might have changed these outcomes. This would mean that the additional potential which may be provided by a softer trampoline is only used when a maximum effort is required.

It also needs to be considered that the force sensors used in this study only measure the normal component of the contact force of the foot with the underlying medium (ground and cloth of the trampoline). It may therefore happen that a different deformation of the foot in the hard and soft trampoline affects the measurement. As an effect of this the calculated momentum results from a force which may not be acting in the same direction over the whole foot-cloth contact period. Moreover, the calculation of the impulse from the insole output alone does not allow to estimate jump height from these measurements. It may, however, been argued that the jump times and the distance travelled after the take-off were unchanged but this can only be based on observations but not on quantitative measurements in this study.
There may also be certain limitations in the hardware used to measure contact forces as the sampling frequency was relatively low with 100 Hz, which may lead to inconsistencies in determining the force onset. Given the mean contact times of about 0.2 s (Table 1) one frame difference would represent a 5% error in total contact time. It may therefore be possible that a better time resolution of the force insoles is needed. According to updates to the measurement system after this study was carried out it is now possible to sample at 200 Hz. At the same time the resolution in amplitude will decrease which may generate other uncertainties.

The reported effect sizes are small for all parameters and medium for the contact time (Table 1). It is therefore well possible that the low sample size in combination with the uncertainty in the timing parameter is the main limiting factor in this study. Future studies should therefore aim at improving the time resolution of the measurement system used while aiming for a larger sample at the same time.

In regard to the use of such modifications to jumping equipment it needs to be noted that coaches and athletes also play with the angulation of the trampoline which is different in different regions and countries. Therefore, future studies need to include this factor in their methods. It may also be considered to apply the measurement of reaction forces on the support of the trampoline to achieve more valid results.

CONCLUSION: In this study, a novel approach of measuring jump-off characteristics from a mini-trampoline was proposed. No differences were shown when comparing a standard trampoline with 40 springs to the same trampoline with only 36 springs. The results of this particular study may indicate that the resulting differences in stiffness are potentially not sufficient to change take-off behaviour. Certain methodological limitations were discussed while it can be concluded that the method may help to advance research on gymnastic jumps when refined and applied over a broader range of performances.

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