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Validation of ergonomic running handgrip elements to improve arm posture of running novices

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Abstract: Running is one of the most popular sports worldwide motivating many non-athletic people to start new physical activities. But especially novice runners are at risk to develop injuries as they tend to run with prejudicial posture. Hence, there has been considerable research to identify factors improving running performance. One of these factors is the correct movement of arms as a swinging pendulum during running. Based on this knowledge ergonomically shaped handgrip elements were designed to improve the posture of the shoulder-arm complex during running. The main objective of this study was the validation of the actual effectiveness on shoulder-arm posture of these handgrips. In this sense 25 adult, healthy persons without running experience were examined by motion capture analysis during running on a treadmill with and without the use of the handgrips. The focus of movement analysis was on changes of hand supination, shoulder abduction and shoulder rotation. Flexion of elbows and shoulders were not expected to change and thus, were investigated as an internal control. Significant changes were found in sense of a reduction of forearm pronation, shoulder abduction, and internal rotation of the shoulder, resulting in improved posture during running. At the same time, no significant changes were found in elbow flexion and shoulder flexion. Future studies are needed to investigate the effects of the detected improvement of arm posture on other important running parameters, such as trunk stability, movement of lower limbs, running economy, and risk of injury. These studies should also compare effects in competitive athletes, recreational runners, and novice runners.

Keywords: Arm posture, Ergonomic hand grip, Motion analysis, Running, Training tool

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1 Introduction

Running sport experiences a veritable boom in the recent past as it supports health prevention and can be practiced with low costs and little effort [1, 2]. But many running novices start without any knowledge about training programs and running technique or posture, hence being particularly susceptible to injuries [3].

However, incorrect running posture can cause overloading leading to typical running injuries that force newcomer athletes to stop their recently started sports ambitions [4]. Hence, any intervention to improve running biomechanics can prevent runners from harm, and in consequence enhances public health [5, 6].

Most runners and even trainers tend to just focus on lower extremities when working on running technique and underestimate the importance of arm positioning [7]. The arm position yet has significant influence on running style and economy [8]. Improved running economy in turn increases running speed despite of constant energy consumption and reduces the risk of injury via enhanced running stability [9].

Important aspects of beneficial arm posture include a loose hand position, the length of the arm pendulum, and arm guidance parallel to the running direction close to the body via shoulder rotation and arm adduction [10].

Innovative ergonomically shaped handgrip elements (LAUFMAUS®) promise to intuitively improve arm posture during running, and hence, running economy. Kinetic chain phenomena and sensorimotor influences are thought to optimize hand position and shoulder-arm-movement during running including hand pronation as well as shoulder abduction and rotation.

Kinetic chain phenomena first were systematically described by Franz Reuleaux [11] and are a meanwhile well-established model to explain the functionality of the lower extremities [12]. It is reasonable to assume that such chain phenomena apply not only to the legs but also to the arms [12].

The aim of the presented study was the quantification of changes in shoulder-arm posture that can actually be achieved by using ergonomic hand grip elements like LAUFMAUS®.

2 Materials and Methods

2.1 Subjects

25 adult volunteers (Table 1) without any apparent musculoskeletal disorders, acute injuries, and pain during walking participated in this study. Participants were recruited through a public announcement describing all the requirements for participation and the study procedures. Only running novices were included. All subjects completed a custom-made questionnaire evaluating pain during walking or running on a numerical rating scale (NRS) to assess current pain severity using a 0-10 scale [13]. Furthermore, neurological diseases and muskuloskeletal disorders were also queried, as well as previous operations with potential influence on walking or running posture.

Table 1: Anthropometric and demographic parameters of study participants.

Participants	Age (±SD)	Height (±SD) [cm]	Weight (±SD) [kg]
15 (Male)	32.6 (±11.8)	180.1 (±6.2)	83.1 (±18.7)
10 (Female)	42.4 (±12.1)	168.1 (±6.0)	72.0 (±9.6)

2.2 Equipment

In line with the target group of running novices, the treadmill Fitifito FT850 (Tamia Warenhandels GmbH, Hamburg, Germany) for the running analysis was used. The subjects' movements were recorded with a 3D motion analysis measurement system (Vicon ® Motion Systems Ltd, Oxford, United Kingdom) with four Vantage 5, eight Vero v2.2 and two Vue reference cameras at a recording frequency of 100 Hz. A plug-in Gait full body model with 38 retroreflective markers was used to analyze the movement of the entire body.

To monitor the cardiological condition, the heart rate was measured with the Garmin HRM-ProTM chest strap (Garmin Ltd., Olathe, United States). The running speed was adapted to a heart rate in a range of 60-80 % of the maximum heart rate, which was calculated as follows [14]:

$$\boldsymbol{Pulse = (211 - age)\ x\ 0.8} \tag{1}$$

2.3 Experimental procedure

Positions of joints of the full body model were defined by using anthropometric data of leg length, knee, wrist and elbow width, hand thickness for each participant. Height and weight of each subject were measured. The fitting size (small or large) of the investigated hand grip element was determined by the distance from the tip of the index finger to the proximo-medial thenar of the hand (small ≤ 16 cm > large) according to the manufacturer instructions. All subjects were analyzed during two direct consecutive runs starting randomly with or without using the hand grip element. Measurements started after participants became accustomed to the treadmill and also reached their custom/individual heart rate plateau. Five measurements of ten seconds each at 100 Hz were recorded from the two different states.

2.4 Evaluation parameters and analysis

Markers first were labeled in order to reconstruct a 3D model. To distinguish the left from the right body half, running cycles were calculated with Vicon ProCalc v1.5.0.

The marker data, trajectories and joint angles were imported into the open source development environment Spyder (v3.8) for the programming language Python.

The joint angles were measured and defined as described in the Vicon ® Nexus Reference Guide. Contrary to the commonly used neutral zero method the plug-in Gait model defines the neutral position of the forearm as maximum supination, negative flexion values (in case of this study for shoulder flexion) are defined as extension.

Postural parameters of the hand-arm-shoulder-complex were compared with and without LAUFMAUS®. These include: hand supination, shoulder rotation and adduction. As an internal control of data validity, the shoulder flexion and the elbow flexion were measured, on which the hand grip elements should not have any influence.

The minima, maxima and mean values with the standard deviation of the respective movements were evaluated. Initially the raw motion data were normalized to the run cycle.

It begins with the heel-strike (0 %) and ends with the ipsilateral heel-strike (100 %).

For each movement (Forearm pronation, elbow flexion, shoulder flexion, shoulder abduction and shoulder internal rotation), the maximum and minimum value in each run cycle was determined. The value maximum or minimum (Table 2), thus corresponds to the averaged maximum or minimum values of all run cycles of all subjects. The mean value (Table 2) is determined of the entire data set of the run cycles.

A paired t-test was performed. Statistical significance was set at $p < 0.05$.

3 Results

Table 2 gives an overview of mean values, maxima, and minima of the measured parameters (±SD) of both arms with and without the use of handgrip elements and the level of significance of changes of these parameters as p-values.

As postulated, a statistical significant reduction of mean values could be measured for forearm supination, shoulder abduction and internal rotation of the shoulder. The loss of internal shoulder rotation was also significant for the measured minima and maxima, whereas just the maxima but not the minima changed significantly for forearm pronation and shoulder abduction.

The parameters of elbow and shoulder flexion, functioning as internal control, showed no changes of mean values and the detected minima. The maxima of these control parameters changed statistically significant just for one arm.

4 Discussion

The results show a significant loss of pronation / increase of supination of the mean value through parallelization of the forearm bones by the use of the hand grip elements. We suggest that a concatenation of this supination with the detected decrease of shoulder abduction and the external shoulder rotation. These observations indicate an improved guidance of the arm pendulum closer to the body and more parallel to the running direction. We suggest that this changes in posture improves biomechanics and therefore running style and running ergonomics.

On the other hand, no significant changes in flexion of elbow or shoulder could be detected. This finding approves data quality as an internal control as these movement parameters were not expected to change during the use of the handgrip elements. The levels of significance for the maxima of these parameters may be interpreted as potential changes that could achieve statistical significance if more subjects would be investigated. This would mean, that even the arm triangle could be improved by using ergonomically designed hand grip elements.

Correct swinging of the arms during running plays an important role as it improves vertical oscillation, counters vertical angular momentum of the lower limbs and minimizes head, shoulder, and torso rotation [15]. Suppressing arm swing can alter several lower limb biomechanics and kinetics. Greater knee flexion and reduced peak vertical force can be observed when arm swing is suppressed, suggesting that leg stiffness decreases, which may explain the reduction of running economy [16].

Hence, the detected improvements of arm posture during the use of the validated running handgrips can lead to improved running posture. Presumably, this also has a positive influence on running economy.

5 Conclusion

We were able to show that important parameters of shoulder-arm posture change by using ergonomic running handgrips. We suggest that this effect improves running economy. This interpretation should be re-evaluated after a period of periodical training. To find out more about the influence of the hand grip elements on the arm triangle, a study with more participants would be needed.

The current data about the influence of arm posture on other important running parameters such as running economy is rather limited [16]. This study is a first step towards a better understanding of changes in arm posture through the use of handgrip elements.

Whether the detected changes really have an effect on other running parameters needs to be evaluated in further studies. In addition, with regard to chain phenomena, it should be further investigated to what extent changes in shoulder-arm posture also influence the rest of the body. This could also lead to improved breathing and running economy.

Future studies are necessary to show the effects of LAUFMAUS® or comparable devices on body posture, lower extremity and running economy not only of running novices but also of competitive or recreational runners.

Furthermore, it should be investigated if non-ergonomically shaped objects held in hands during running have similar effects on shoulder-arm posture of runners.

Table 2: Table of the angular change of the minima, maxima, and mean values of the left side without hand grip element (LS), the left side with hand grip element (LS_LM), and the right side (RS) and the right side with hand grip element (RS_LM), along with the corresponding standard deviation (±SD) p-values. Significant changes are marked with a "*". The mean value was calculated over all data points of the run cycle, whereas the minima and maxima were determined once per run cycle, from which the mean value was calculated.

		LS (±SD) Angle [°]	LS_LM (±SD) Angle [°]	p-value	RS (±SD) Angle [°]	RS_LM (±SD) Angle [°]	p-value
Mean	Forearm pronation	116.01 (±17.95)	105.87 (±21.28)	p = 0.022*	125.13 (±13.35)	115.56 (±21.11)	p = 0.017*
	Elbow flexion	102.96 (±14.90)	103.94 (±10.16)	p = 0.599	99.18 (±11.73)	99.30 (±11.36)	p = 0.938
	Shoulder flexion	-22.38 (±7.70)	-23.23 (±6.65)	p = 0.107	-25.53 (±5.96)	-25.66 (±5.29)	p = 0.807
	Shoulder abduction	24.35 (±5.76)	23.00 (±6.88)	p = 0.034*	26.45 (±6.68)	25.37 (±7.77)	p = 0.035*
	Shoulder internal rotation	32.20 (±7.90)	24.28(±9.20)	p < 0. 001*	28.93 (±10.52)	22.38 (±10.94)	p < 0. 001*
Minimum	Forearm pronation	109.17 (±18.59)	99.05 (±25.40)	p = 0.073	119.38 (±18.79)	109.05 (±29.04)	p = 0.061
	Elbow flexion	92.80 (±17.06)	96.50 (±12.37)	p = 0.087	89.23 (±13.61)	91.28 (±14.12)	p = 0.306
	Shoulder flexion	-40.76 (±8.89)	-40.42 (±8.17)	p = 0.634	-43.68 (±6.72)	-43.33 (±6.22)	p = 0.589
	Shoulder abduction	18.54 (±6.38)	18.04 (±7.00)	p = 0.396	20.37 (±6.74)	19.82 (±7.72)	p = 0.168
	Shoulder internal rotation	24.56 (±8.71)	16.92 (±9.47)	p < 0. 001*	21.99 (±11.73)	15.06 (±12.28)	p < 0. 001*
Maximum	Forearm pronation	123.46 (±17.41)	112.21 (±19.97)	p =0.003*	131.11 (±12.52)	122.68 (±16.90)	p = 0.010*
	Elbow flexion	115.11 (±12.01)	113.15 (±8.27)	p = 0.196	113.41 (±9.17)	109.95 (±8.27)	p = 0.007*
	Shoulder flexion	-4.96 (±10.97)	-7.05 (±10.23)	p = 0.004*	-7.58 (±9.05)	-8.82 (±9.32)	p = 0.082
	Shoulder abduction	30.94 (±6.14)	28.63 (±7.70)	p = 0.003*	32.68 (±8.17)	31.19 (±9.43)	p = 0.029*
	Shoulder internal rotation	40.03 (±7.84)	31.46 (±10.45)	p < 0. 001*	36.46 (±10.35)	29.31 (±11.50)	p < 0. 001*

Author Statement

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