Tailored feedback requirements for optimal motor learning: A screening and validation of four consumer available running wearables

Proceedings

Tailored Feedback Requirements for Optimal Motor Learning: A Screening and Validation of Four Consumer Available Running Wearables †

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Abstract: The pervasiveness of wearable technology has opened the market for products that analyse running biomechanics and provide feedback to the user. To improve running technique feedback should target specific running biomechanical key points and promote an external focus. Aim for this study was to define and empirically test tailored feedback requirements for optimal motor learning in four consumer available running wearables. First, based on desk research and observations of coaches, a screening protocol was developed. Second, four wearables were tested according to the protocol. Third, results were reviewed, and four experts identified future requirements. Testing and reviewing the selected wearables with the protocol revealed that only two less relevant running biomechanical key points were measured. Provided feedback promotes an external focus of the user. Tailoring was absent in all wearables. These findings indicate that consumer available running wearables have a potential for optimal motor learning but need improvements as well.

Keywords: running technique; biomechanics; wearable; feedback; external focus; tailoring; engineering requirements

1. Introduction

This study aims to identify, empirically test and validate tailored feedback requirements for optimal motor learning in four consumer available running wearables. In this introduction the concepts of running technique, optimal motor learning, and running-related wearables are described. Then, the methods are put forward. A mixed-method approach was adopted to identify running biomechanical key points and optimal motor learning principles, and to screen and validate these in four consumer available running wearables. Finally, the results and implications for sports engineering are discussed.

1.1. Running Technique

Running, with interesting qualities such as accessibility and ease of practice, has become increasingly popular among the general population as a primary form of exercise [1,2]. It is mostly performed outside a sports club [3] with the assumption that running has several health benefits [4]. However, it is also known that many, mainly in novice runners, drop out and get injured due to lack of guidance and proper running technique [2]. Although the exact influence of running technique to drop-out is still unclear, it is hypothesized to be of fundamental influence for achieving health and physical activity goals within runners [5,6].

To describe and classify running technique the running cycle [7,8] and attractor-fluctuation landscape of dynamic systems [9,10] can be used. Running technique is described in biomechanical key points, which are the biomechanical parameters that are related to running economy or performance [7]. Proper running technique is well documented in relation to running economy measured within a laboratory environment [11]. The identified biomechanical key points in this study are less leg extension at toe-off, larger stride angles, alignment of the ground reaction force and leg axis on impact and low activation of the lower limb muscles [11]. The constraints on the running performance in the real-life running context are different from the laboratory environment [10]. This may influence the biomechanical parameters related to running economy in the real-life running context as well.

1.2. Optimal Motor Learning Principles

Wulf and Lewthwaite [12] proposed a new perspective on motor behaviour and learning, the OPTIMAL theory (Optimizing Performance Through Intrinsic Motivation and Attention for Learning). In this theory motivation and implicit learning meet to create optimal motor learning strategies. In the motor learning strategy that is suggested as most beneficial the learner has autonomy, enhanced expectancies, and an external focus of attention. First, autonomy can be promoted by giving the learner a degree of influence and choices within the learning process. Second, enhanced expectancies can be improved with positive feedback. The learner also gains self-efficacy, confidence in future performance success, and motivation in learning with positive feedback [13]. Third, external focus is promoted when feedback on the outcome (result) of a movement in the environment is provided (i.e., knowledge of result (KR)). Feedback on the kinematics or body parts (i.e., knowledge of performance (KP)), directs the learners' attention to an internal focus. This enhances self-focus which is detrimental to motor learning. Another important motor learning strategy implies that external feedback should be complementary to the intrinsic feedback [14,15]. This can be done by providing multi-model feedback (combination of visual, auditory and haptic feedback), taking advantage of each modality of feedback. Preferably the feedback modality is adapted to the type of user [1,2].

1.3. Wearables and Running Technique

Within the extensively growing market of sports-related electronic monitoring devices, dozens of consumer available products aim for improving performance or learning. Wearables that use a combination of sensors (accelerometer, gyroscopes, and magnetometers) are capable of detecting sport specific movements in a wide range of environments [16]. To improve performances, wearables do not only measure running biomechanical parameters but also provide feedback to the runner in context. The question, however, arises whether these wearables address the proper motor learning strategies. Within this study, the addressed theoretical framework will be used to develop motor learning requirements for engineering consumer available running wearables. These requirements should target the use in a real-life running context and be tailored to the user [1,2].

2. Methods

2.1. Screening Protocol Development

The screening protocol was developed based on literature review. The protocol was composed of four topics: (i) running biomechanical key points (i.e., running technique); (ii) feedback (i.e., optimal motor learning); (iii) instruction and motivation (i.e., optimal motor learning); and (iv) individual tailoring. Next, a qualitative analysis was performed to identify commercially available products that analyse running technique. Devices were included that (i) measure running biomechanical parameters; (ii) wear on the shoe or the chest; and (iii) provide real-time feedback on a smartphone application. Previous research provided evidence for novice runners' preference for smartphone applications [1].

Six running coaches were observed for: (i) feedback timing; (ii) visual and; (iii) auditory feedback content; and (iv) multimodal feedback, while coaching recreational runners. Observations by event sampling (in counts) were used to identify biomechanical parameters and motor learning strategies additional to the desk research. Observations lasted one complete training session in which warm-up, running drills, running session and cool-down were implemented. A qualitative, structured, non-participating and indirect observation technique was used for this study phase.

2.2. Empirical Testing of the Wearables

Three researchers tested the identified wearables on three running sessions to identify the given feedback and the biomechanical parameters as stated in the protocol. All sessions were completed within a real-life running setting. During the running sessions, screenshots were taken by the researchers at three key moments, in particular (i) when given feedback or instruction; (ii) during the last 15 seconds of each running interval; and (iii) immediately after the running session.

2.3. Focus Group with Running and Motor Learning Experts

A focus group with four experts in the field of running technique and motor learning was organized to identify the running biomechanical key points, and optimal motor learning strategies. The identified parameters were categorised using MoSCoW method [2,17]. The goal was that the experts came to a consensus with regards to the categorisation of the parameters.

First, all running biomechanical parameters within the developed screening protocol and the results of the empirical testing of the four wearables were introduced to the group. Running biomechanical key points were identified and categorised by discussing the parameters and come to consensus. Additional parameters or more specific parameters were taken into consideration as well. Second, optimal motor learning principles were discussed and categorised. Third, the group reviewed the categorisation outcome.

3. Results

3.1. Screening Protocol: Desk Research and Observations

Three devices were included in the desk research: Stryd footpod (Stryd, Boulder, Colorado), Wahoo TICKRx (Wahoo Fitness, Atlanta, Georgia), and SHFT (SHFT, Copenhagen, Denmark). These devices measure running biomechanical parameters with a shoe or chest wearable and provide feedback through a smartphone application. For reference purposes, Garmin HRM-Run™ was also included, this device provides feedback through a sports watch.

Observations of the running coaches showed that arm swing, body posture, ground contact time (GCT), high knees, and rhythm were coached as running biomechanical parameters. Primary interventions to improve running technique were variations of running drills, such as knee-ups, heel-ups, accelerations, etc. Instructions through an example given by the coach, and by the runners in the group themselves were observed 16 times. KR was absent while KP was provided on 86 counts and was directed to different key points e.g., running posture (31 counts), high knees (10 counts), and arm swing (6 counts). Other feedback was provided towards the tempo of the drills' execution (11 counts). Furthermore, positive coaching was performed on 51 counts.

The four topics of the screening protocol covered 95 different parameters: (i) 40 running biomechanical related parameters; (ii) 28 feedback related parameters; (iii) 22 instruction & motivation related parameters; and (iv) 5 individual tailoring related parameters. This screening protocol was used to empirical test the devices.

3.2. Empirical Testing

The running biomechanical parameters measured by all selected devices were cadence, GCT, and vertical oscillation (VO). Stryd and SHFT also measure power and running efficiency. Furthermore, SHFT measures impact force, landing foot angle, braking G, foot strike, toe off angle, and air time. Stryd measures form power and leg spring while Wahoo TICKRx measures smoothness in three directions. Feedback provided in real-time by Stryd is, visual feedback displayed in numbers on power and cadence. After the training session, it provides feedback on running efficiency, GCT, leg spring, and VO as well. TICKRx provides real-time, visual feedback with numbers on cadence, GCT, and VO. Smoothness is also visualised with colours and a bar chart. Garmin HRM-Run™ (Garmin International Inc., Olathe, Kansas) provides real-time, visual feedback displayed in numbers on cadence, GCT, and VO. One of these parameters, as chosen by the user, can be visualised as well. SHFT provides real-time visual and auditory feedback on power and a pre-selected parameter. This parameter, in this study cadence in all three researchers, is selected by the built-in screening of running technique. After training SHFT provides feedback on running efficiency, GCT, VO, impact force, landing foot angle, braking G, foot strike, toe off angle, and air time. SHFT is the only selected wearables that provides feedback according to an individual reference. Instruction on running technique is provided by SHFT only. Motivation is present as 'incidental choices', the user can choose a parameter that will be feed backed in SHFT and Garmin HRM-Run™.

3.3. Focus Group

Consensus was reached for the categorisation of the running biomechanical key points as listed in the first column in Table 1. The other remaining parameters were identified as irrelevant for running technique analysis. According to the experts the biomechanical parameter minimal impact force, should be more specific and adjusted to minimal jerk at impact. In addition to the listed parameters, the experts added two parameters, the travel of the ground reaction force projection in the foot within the whole stance phase and the rotation speed of the hip joint in stance phase as both categorised as a 'Must Have'. General result on running biomechanical key points was that all key points should be analysed with running pace as reference and with all key points combined.

Feedback principles as categorised by the experts are listed in the second column in Table 1. Feedback and interpretation of biomechanical key points must be done according to an individual runners' reference with a bandwidth defined from the last couple of runs. This 'Must Have' is also related to individual tailoring. Feedback to the runner 'Must Have' visualised form using KR.

Instruction & Motivation categorisation is displayed in column 3 in Table 1. Control and autonomy over practice are categorised as 'Must Have'.

Table 1. Results of the focus group displayed as future requirements, categorised by MoSCoW.

	Running Biomechanical Key Points (Pace Referenced)	Feedback	Instruction & Motivation	Individual Tailoring
Must	Cadance Vertical oscillation Braking impuls duration Minimal jerk on impact Impact force direction Hip rotation speed stance phase Travel ground reaction force projection in stance phase Body angle	Individual reference bandwidth Based on last couple sessions Visualised KR Injury preventive Positive feedback	External focus of attention Self-efficacy expectations Perceived task difficulty Control over practice situation Autonomy supportive language	Easy Goals Feedback based on individual screening
Should	Acceleration and deceleration of the lower leg before impact Minimal impact G Hip lock in stance phase	Fatigue induced Biomechanics combined with physiological variables Trend analysis Context and situation based feedback Variation in feedback forms	Incidental choices Encouragement	Ease of use Share with the coach
Could		Alarm with great deviations Self-modelling Social comparative	Database with correction exercises	Share with team mates Share on social media
Won't	Measure only one key point	Real-time KP		

4. Discussion and Conclusions

In this paper results of desk research, observations, empirical testing and a focus group were combined to identify and list tailored feedback requirements for wearables that aim to improve running technique.

All identified parameters in the focus group were reviewed with literature. Identified Running biomechanical key points in the focus group are consistent with key points with proven relation with running economy [11] or identified in consensus as performance determining by the experts in the focus group. The results state that biomechanical key points 'Must Have' an optimal individual bandwidth relative to running pace. The wearables within this study only measure two (Stryd, Wahoo TICKRx, Garmin HRM-Run™) or four (SHFT) relevant biomechanical key points. Only SHFT uses an individual based bandwidth. This study complies to other studies for proper running technique analysis and understanding by analysing a combination of key points of the individual runner [7]. From that understanding, an individual profile on running technique can be built which should be able to evolve over time. The individual bandwidth per key point changes over time because the running technique will change over time through learning. This requirement can be met by calculating the mean per key point from a number of earlier sessions combined with an upper and lower limit.

When the wearables are compared to the OPTIMAL theory [12], only external focus is promoted by providing KR feedback. According to this study this feedback is however directed at several biomechanical parameters that are not adopted as biomechanical key points. Feedback is also provided per parameter instead of a combination of parameters. Autonomy and enhanced expectancies are not promoted with the wearables within this study, users can only choose parameters on which feedback will be provided. These results raise the question whether the strategy used by the wearables is beneficial for OPTIMAL motor learning.

Taking a closer look at the feedback modality learns that all measured data is provided in visual and/or auditory form in numbers. A couple of biomechanical parameters are also visualised with colours or bars to give an interpretation of the key point. The used references are however not individually based on earlier sessions. Requirements on feedback are: (i) providing feedback on the combination of key points; and (ii) translate feedback into visual and/or auditory feedback with no interpretation. Promoting autonomy can be met when the runner can choose, from a relevant pre-selection, on which biomechanical key points the feedback is focused. According to Vos et al. [2] the pre-selection should be made by taking the type, preferences, and experiences of the runner into account for tailoring. Alternatively, the selection of the feedback modality can promote autonomy as well. From literature is known that enhanced expectancies can be promoted by providing clear and achievable goals for short- and long-term and positive feedback when goals are met [12,13].

In conclusion, consumer available running wearables promote an external focus of attention but not on the relevant biomechanical key points determining proper running technique. Improvements can be implemented in providing feedback without interpretation from the combination of all key points. Tailoring and motor learning can be improved by taking earlier sessions as a reference for constructing the bandwidth of key points. The requirements identified in this study provide added value for engineering and designing technology aimed at motor learning and/or improving performance. Specific requirements for feedback, instruction and motivation and individual customization are applicable to a large number of sports.

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