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The controversy and pragmatic resolution of the introduction of foot sensors in competitive race walking

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ABSTRACT

The adoption of new technology can have a controversial or profound impact upon a sport and how it is performed. Recently, there have been proposals of the potential implementation of sensors in athletes' footwear to help reduce illegal gait activity during competitive race walking events. This paper investigated the potential impact and implications with this technological introduction. This study utilises a previously peer-reviewed framework proposed for sports technology inclusion discourse and then applies it to the proposed use of foot sensors in race walking. Subsequent to undertaking further scientific inquiry to ascertain whether such technology would cause either significantly disproportionate performance enhancement or injury, it is ultimately proposed on balance that such sensors are appropriate for use in competitive race walking.

1. Introduction

Generally speaking, the innovation, design and application of technology used in competitive sport is of paramount importance to athletes looking to optimise their best possible performance or to help regulate how it is performed by its participants [1]. It was reported in the athletics press that it was being investigated that sensors – likely positioned in the shoes, should be used to help regulate the biomechanical and gait behaviour of athletes in the sport of race walking [2,3]. The governing body were later quoted as stating that "implementation of the technology to assist judges to identify athletes who have lost contact with the ground would only be adopted in 2021 if the necessary tests, introduction and distribution of the insole chips are concluded by the end of 2020" [4]. The results of this trial have not been reported to date but this may not be surprising given that the stated timeframe of this trial later coincided with the Covid-19 global pandemic in 2020. This pandemic saw many sports activities (such as the Olympic Games themselves) delayed or postponed.

There have been several circumstances whereby technology in sport has been proposed as generating some degree of controversy. For example, these have included the use of swimsuits in swimming [1] or novel ball designs in golf [5]. Furthermore, when relating to feet or footwear there has been technological-based controversy with the use of prosthetic limbs for running [6], the use of prosthetic limbs for long jumping [7], speed skating footwear [8], the use of the 'brush shoe' track spike design [9] and the use of the Alphafly/Vaporfly shoes [10]. As a result, some caution may well be advised before adopting any level of technological change.

Race walking itself is a sport that requires an athlete to race over a given distance as fast as possible using the locomotive method of walking (rather than running) and this activity has been investigated in few scientific studies generally [11] and published within the last 10 years. This sport has been defined by World Athletics as: 'Race Walking is a progression of steps so taken that the walker makes contact with the ground, so that no visible (to the human eye) loss of contact occurs' [12]. 'The advancing leg must be straightened (i.e. not bent at the knee) from the moment of first contact with the ground until the vertical upright position'. If the ground contact is visibly seen to have been lost or whether a bent knee is witnessed any point of the gait cycle, this is judged illegal and colloquially known as 'lifting' [13]. The nature of race walking is defined by the governing body, World Athletics, specifically under Rule 54.2 [12]. [14]. The adjudication of lifting is overseen by a group of judges who observe the athletes throughout their racing event. Under rule 54.5, if a judge is not completely satisfied that an athlete is *fully* complying with Rule 54.2, they show the athlete a yellow paddle that acts as a warning. However, if a judge observes a visible loss of contact or a bent knee *during any part of the competition*, the judge shall send a Red Card to the chief judge. Ultimately, if three red cards from three different judges have been sent to the chief judge regarding the same competitor, the athlete would then be disqualified [12].

However, whilst shoe sensors are not currently used to monitor gait infringements, the accuracy and precision to measure lifting robustly

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has already been investigated [14] and subsequently quantified [15]. The Hanley et al. study revealed that flight times shorter than 0.033 s were detected by fewer than 12.5% of judges. This thereby indicated a non-visible loss of contact and a non-application of the rules. Flight times between 0.040 and 0.045 s were only detected by three out of eight judges. Very long flight times (≥0.060 s) were detected by nearly all the judges. It should be noted that these thresholds were reported to correspond to race walking speeds of ~14 km/h for men and 13 km/h for women [15]. It was also suggested that for certain techniques, a degree of learned skill by judges is involved. These limitations regarding rule infringement visibility bolsters the more recent proposal by the sport's governing body that a more objective and reliable source of technology (such as the use of the aforementioned foot sensors) could be beneficial. Whilst the current emphasis by the governing body is seemingly focused on foot-based sensors, it should not be assumed to be the only viable method to measure race walking gait. Indeed, recent studies have also investigated alternative methods such as video analysis [16] or inertial sensors located on different regions of the body [17]. The use of foot-based sensors has been validated though [18,19] and that if detected, a fault in the athletes gait does then moderate the athlete's behaviour as a result [19]. Whilst it could be assumed that many technological innovations are generally intended to improve athletic performance, some examples are intended to help regulate the sport itself by monitoring human physical behaviour. For example, sensors such as 'Hawkeye' have been used to determine illegal service of balls in tennis or when a football is deemed to be out of bounds in soccer [1]. Whilst foot sensor technology would seemingly address the need for fairness within the sport in a similar fashion, it is a fundamental change to how it is currently regulated. This proposal has not considered the wide range of philosophical issues that have been reported in such discussions before [20], coupled with the broader debate that such controversy is proposed to require [1]. The various factors surrounding the implementation, fairness and impact of sports technology was summarised by Dyer, [1]. This study undertook a systematic review which ultimately resulted in 31 reported cases of sports technology controversy which led to an 11-item summary of factors that resulted with the inclusion of sports technology [1]. This summary is reproduced in Table 1.

The issues that surround the application of criteria like those highlighted in Table 1 is that such debates can be highly philosophical and can provide a lack of actionable outcomes. For example, whilst some studies debate the philosophical acceptability of sports technology [10,20,21], such research can sometimes adopt what would be seen as an unrealistic utopian ethos [22]. As a result, the authors proposed outcomes can often lack the means to resolve the problem pragmatically [10]. The implementation of a pragmatic approach is particularly pertinent to the race-walking foot sensor adoption case as this discourse is directed at an Olympic sport with long standing traditions. As a result, this paper will apply the Dyer framework to the proposed use of footwear-based sensors in competitive race-walking and to determine if this new form of sports technology would be considered appropriate if it were introduced.

Table 1
Summary of sports technology impact.

Criterion
Harm or health (to the athlete or others)
Un-naturalness
Unfair advantage
Coercion
Safety & spectator appeal
Integrity of the game, harm to or advantage over the sport itself, or the 'spirit of the sport'
Deskilling & reskilling
Dehumanisation
Cost (or excess cost)
Equal opportunity or access

2. Methods

The potential impact of the race-walking foot sensors was investigated by reframing the contents comprised in Table 1 as questions. These questions were constructed by adopting the pragmatic lines of inquiry as recommended by Bartle and Shields [23]. This adoption would mean that the resulting discussion would be suitable for the sports stakeholders such as its governing body to then review and implement. Stakeholders for a sport have been typically suggested to include athletes, coaches, judges, researchers, medical practitioners and spectators [24]. These questions were then addressed by utilising the existing peer-reviewed literature and adopting a similar structure to previous studies that have explored the legality of technological issues in sport [20,21,25]. For brevity, the proposed technology will subsequently be referred to as 'shoe-based sensors' (SBS) in this paper.

The adaptation of the pragmatic research questions in Table 1 were reformulated as follows:

- Is the introduction of SBS harmful to the health of the athlete using them ?
- Are SBS unnatural ?
- Do SBS provide an unfair advantage ?
- Could the introduction of SBS coerce race walking athletes to want to use them ?
- Does the use of SBS contribute towards spectator appeal ?
- Does the use of SBS affect the integrity of the sport or provide an advantage over the sport itself ?
- Does use of SBS deskill or reskill the sport ?
- Does the use of SBS somehow dehumanise the sport ?
- Could the financial cost of SBS be a barrier to race walking as a sport ?
- Is SBS technology inaccessible to some athletes ?

3. Results and discussion

3.1. Is the introduction of SBS harmful to the health of the athlete using them?

The *harm* criterion is in relation to any injury or damage inflicted on an athlete's health either directly or via side-effects as a result of a sport technologies use [26]. It is conceivable that any new form of sports equipment or technology could cause more harm than those it seeks to replace or could create a negative bi-product known as a 'revenge effect' [27]. However, in this case, this would not be known until SBS are in service and with data obtained to see if any forced change in human behaviour leads to a higher incidence of injury. Running shoes in general have already been investigated regarding their influence on injuries due to their resulting changes to a runner's biomechanics [28]. In the case of additional technology to footwear such as SBS, this could also be in the form of their additional mass. Whilst the magnitude of shoe mass could be seen as arbitrary, this has been proposed to contribute towards negative performance [29,30] or acts as a deviation from the athletes nominal shoe mass which could then contribute towards athletic injury [31]. Whilst such studies often do not isolate the shoes mass from its cushioning or motion control aspects, it was reported that a shoe mass addition of 50 g could still affect performance [32]. Finally, as the final form of the SBS is not known at this time, it is also conceptually conceivable that such technology could also be invasive to some degree and therefore be possible it could lead to superficial foot damage such as blisters and abrasions. As a result, it would be advisable that SBS should only be included if they are of the lowest possible mass and should be subject to scientific enquiry to ascertain what injury risks to athletes exist in reality. As a result, it could also be proposed that provided this mass is in keeping with other such-like contemporary technology (such as watches and heart rate monitors) it would seem an unwarranted concern with respect to SBS.

3.2. Are SBS unnatural?

'Naturalness' has been proposed as an entity that tampers with the body and interferes with nature. In this case, use of the entity would lead to a performance that could not be achieved without it [26]. The definition of whether a form of technology is 'unnatural' to its user or not could be argued to be moot when it is conceded that most sports products are man-made and unnatural entities to begin with [10]. It should be noted that running shoes already act in an unnatural manner as they manipulate the biomechanical patterns that the athlete may not be able to obtain without them [32]. Therefore, both footwear and any sensors are unnatural and contribute to unnatural behaviour. Due to decades of use in service already, it would not be realistic to ban footwear on this argument alone.

Furthermore, runners consciously control their race-walking gait by seemingly adhering to the 'straightened knee' aspect of the rules. However, at race speed it is possible that they do not observe the 'no loss of ground contact' part of the rule. Pavei et al. [11] would support this supposition by suggesting that walkers did not observe the 'no flight rule'. It should also be noted though that their interpretation of the rule was based upon the characteristic of being 'non-flight' in nature. This differs from that of the sports rulebook so is in error. Either way, this would suggest that there is some level of conscious control over how an athlete chooses to perform race walking locomotion and means they could regulate themselves if needed.

Whilst the sensors are charged with detecting a specific biomechanical infringement, they are ultimately charged with the measurement of the athletes' output behaviour. However, the studies that have evaluated such sensors so far have not evaluated if the athletes race walking style would change in any way to achieve that aim. If the visual behaviour of the race walker becomes exaggerated to compensate for the sensors sensitivity, this could be debated to be seen to be an increasingly 'unnatural' method of locomotion. This argument could be countered however, by accepting that if the cultural norm is to walk at a velocity which produces the lowest metabolic cost [33] but competitive race walking typically can already be conducted at a velocity of circa 14 kph [34], that this is already unusual in appearance and behaviour anyway. This is pertinent when such velocities are typically associated with running or jogging, not walking. As a result, there is a precedent already in place and this technology is no more unnatural from those already in service.

3.3. Do SBS provide an unfair advantage?

It could be assumed that since the SBS are introduced universally to the sport, any impact would then be equally shared by all competitors. Or alternatively, this equal application of technology assumes the resulting equal penalty to all athletes. However, athletes are not the same size and total mass. Whilst the sensors may not offer an unfair advantage alone as such, it could be argued that they apply an unfair penalty as the weight increase of the SBS would be proportionally different with respect to each athlete who also varies in mass. It would result in a different total percentage of an athlete's overall resulting body mass. Ultimately, the three outcomes of this could be:

- To issue the same sensor to all athletes under the guide of being an equal addition.
- To proportionately increase the sensors mass based on the body mass of each athlete it is attached to so that the proportional increase is the same.
- To accept that despite its principle unfairness, this degree of unfairness as minuscule when used in reality.

It is felt that scientific inquiry would determine the best approach by deeming what level of metabolic or running economy cost exists based on the SBS in its final form, position and application to a suitable sample group population. However, there is evidence that the role of footwear mass is relevant to an athlete's locomotive performance. For example, the effect on running economy of carrying extra weight on the foot has been shown to be significant with additional masses of both 50 g and 100 g [29] or ultimately during running then being measured at 1% per 100 g per foot [30]. Whilst several studies have investigated and successfully validated inertial or piezoelectric sensor technology for race walking [17,36–39], these do not seemingly report the mass of the proposed technology to then be able to estimate their impact on the race walkers performance. It should be noted that in some of these studies, the sensors were not located on the shoes [36,38–40]. However, if an arbitrary example of a 10 g sensor was used, whether the subsequent performance impediment of 0.1% as conceived by Frederick [35] could be considered significant enough in reality would determine whether the pursuit of SBS is truly fair. Whilst much of this evidence is levelled at runners and not race walkers, it is a fair assumption that additional mass would have an effect and its impact on differently sized athletes should not be ignored without further scientific inquiry.

3.4. Could the introduction of SBS coerce race walking athletes to want to use them?

Coercion has been proposed as an effect whereby athletes have been pressured to use technology [41]. A contemporary example of this has been through the use of performance enhancing drugs in order for them to remain competitive. However, since the sensors are to be implemented universally within the sports constitutive rules, any claims of coercion, whether valid or not would be proposed here to be ultimately moot.

3.5. Does the use of SBS contribute towards spectator appeal?

It is unlikely that it is known whether these sensors could provide additional appeal to spectators as they have not been formally introduced into the sport to date. Furthermore, no studies to date have investigated spectator or fan behaviour specifically with respect to race walking. However, Wann [42] proposed a scale to understand sports fans motivations in general. This scale identified eight factors that comprised a spectators motives including: eustress, self-esteem, escape from daily life, entertainment, economic factors, aesthetics, group affiliation, and family needs. From these, the sensors appearance may only fall under the 'aesthetics' and 'entertainment' criterion. Shoes by themselves are a relatively small visual component of a race walkers appearance and are hard to see during a race due to being in a constant state of motion. Flight time for a race walker has been proposed to be as little as 0.01–0.05 s and noted that even race walking judges could not detect such short flight durations due to the psychophysiological limitations of vision [11]. It is conceivable though that the sensors could indirectly create entertainment for spectators via the introduction of data 'gamification' to spectators. Gamification is an enhanced positive pattern or interaction in service use, such as with increasing user activity, social interaction, or quality and productivity of actions [43]. For example, by sharing with spectators' the visual, multimedia or graphical means of rule infringements, this could provide added intrigue and interest to the event beyond that of the current coloured yellow or red hand paddles currently used by the event officials to signify rule 54.2's infringement [12]. The avoidance and occurrence of gait illegality may become an attractive feature by spectators of the sport in itself.

3.6. Does the use of SBS affect the integrity of the sport or provide an advantage over the sport itself?

The transition from human judgement or officiation to sensor-based decision-making has already occurred in other sports such tennis or football [1]. In both cases, this shift was made to improve the robustness of the decisions of the human referee which had been cited as making a proportion of errors in their judgement [1]. Despite this technological introduction, the aesthetic representation of the sport is not changed as human officials and referees still arguably remain present in such cases. It is unclear whether SBS will provide absolute ruling of gait rule infractions or whether it will only augment human officiating decision making. However, it has been reported that if a hybrid approach of both human officiation and sensors are used together, it should be noted that the human officiate is still heavily influenced by such sensors. This has been reported with sensors such as Video Assistive Refereeing in football [44]. Without the sensors having accumulated an appropriate volume of 'in-race' data or any longitudinal studies taking place of their implementation, it's arguably difficult to know at this time whether the conceptual integrity of the sport could be altered or affected in any way.

Whether the technology changes the integrity of the sport remains unclear until a significant proportion of the sport use SBS under competitive conditions. It is unclear whether such athletes will now moderate their in-race behaviour as a result of SBS use. Furthermore, whilst being introduced with the best of intentions, it is unclear if any revenge effects [27] will occur as a result of their introduction and change the sports nature, philosophy or behaviour. This all said, the question regarding whether such sensors provide an advantage over the sport itself could be seen as negligible due to all competitors being required to use the same sensors and their design being universal in nature. However, as per the discussion in the 'unfair advantage' criterion, it cannot be assumed that an equal introduction has an equal outcome.

3.7. Does use of SBS deskill or reskill the sport?

A key question is whether use of the foot sensors could hypothetically reskill or deskill the sport. Deskilling is whereby a sport is simplified or made through the introduction of technology [45]. Alternatively, re-skilling is whereby the sports needs or behaviour is somehow changed through the introduction of technology [1]. It could be argued that the sport has not been damaged from its current ethos in terms of its needs or its internal goods as race walking's relative nature would remain the same. However, this situation has occurred before when technological changes took place, such as with the change in playing surfaces from clay to grass courts in tennis altering what type of players were favoured [46]. This said, it could be argued that if SBS are intended to police infractions such as lifting, it is unlikely that they would deskill race walking as they are fundamentally intended to guide how the sport is performed rather than changing the environmental conditions or to improve performance. If anything, their intended added robustness may actually upskill the sport to make it more challenging to perform if SBS are intended to enhance human official decision making and apply more rigour as to how it is undertaken.

The impact of SBS on how the sport is performed is unclear until the mass, position and design of the sensor is disclosed and identified by the sport's governing body. This could be considered pertinent when it has been demonstrated that the behaviour of the upper body of race walkers is linked to the mechanics and visual behaviour of their lower body [47]. If the athlete feels they have to moderate their current technique in any particular way due to the SBS position or mass, this connection may have ramifications for the athlete's biomechanics. If the sensor can detect something more robustly and reliably than something the current judges struggle to Ref. [11], this may make athletes have to apply a greater degree of care to their technique. This in turn, if affecting current levels of undetected flight time, could impede the athlete's performance until such time as they could refine their abilities to accommodate this reduced level of tolerance. This issue could also be affected by the shoe sensors disclosed measurement accuracy, precision and level of error. Ultimately, until a system is tested and validated, this would not be known at this time.

Crucially, the act of winning an event still requires the best possible effort to achieve it but it is argued that any marginal changes in the execution of race walking could represent a significant change for its performance success [48]. Therefore, the introduction and impact of SBS should not be assumed to be negligible nor assumed to see the same outcome when applied to different athletes' who may have different nuances in their walking technique [15].

3.8. Does the use of SBS somehow dehumanise the sport?

The question derived from the framework asked whether the use of the SBS somehow dehumanise the wearer or their appearance? The dehumanisation of a user through the adoption of technology is a concern when debating whether sports technology is ethically appropriate [49]. However, the use of the sensors would seemingly change little with the visual appearance of the runner due to their likely small size overall and proportion in relation to a contemporary running shoe and the human body. It would also be difficult to suggest that they dehumanise the athlete any further than current race walking footwear or heart rate monitors and watches. However, the addition of this technology does provoke further discussions surrounding that of *cyborgification*. Cyborgification is a hybrid relationship between a human body and artificial technology [50]. In this case, whilst not permanently affixed, there is a direct relationship arguably established between SBS and the athlete and any behavioural change as a result. Whilst some level of cyborgification precedence has already been proposed to exist in competitive sport in terms of athletes with a disability [50] or the use of prosthetic limbs [51], further proposals such as SBS could provide further discussion surrounding any 'slippery slope' or the uncertain acceptable boundary between humans and the technology they use.

3.9. Could the financial cost of SBS be a barrier to race walking as a sport?

It isn't clear whether SBS would be supplied to athletes by organisers for a specific event only or whether the athletes will be expected to purchase these themselves. This difference is important as it could increase the required expenditure by athletes to participate in a sport [1]. It has been proposed that sports technology can act as a barrier to the levels of participation because athletes are deterred by the high cost of sports technology or any necessary training equipment [45]. As a result, the two fundamental choices are via race organiser supply or by athlete purchase. If the organisers aim to minimise the cost to the athlete by supplying it themselves, this could still lead to further unfairness because it may be wise for athletes to train with this technology throughout their training year to maximise their abilities using it. This is pertinent when it has been proposed that athletes moderate their race walking technique based upon feedback of their technique [19]. Alternatively, if athletes are expected to purchase SBS themselves, the relative disparity of wealthy to poor nations [45] makes it hard to ascertain what could be considered an unacceptable degree of cost. Without an assessment of the sports stakeholders, it is not known whether this is acceptable within the sport of race walking.

3.10. Is SBS technology inaccessible to some athletes?

As mentioned with respect to the aforementioned discussion surrounding cost, what is not clear is how the SBS will be supplied to athletes. It is also not clear whether the sensors are supplied to the athlete at the point of competition and retro-fitted to their existing shoes or require specialised footwear that the SBS are placed within. As was inferred under the reskilling criterion discussion, the use of such technology may require technique refinement or re-training entirely as the shift from human-based assessment to machine detection cannot be assumed to be identical or interchangeable. Subsequently, there may be issues that all athletes scattered internationally may possess, such as those raised in terms of technological cost and access [1]. At which point, the cost and supply chain are both concerns because this imbalance could provide an advantage to some athletes who can train with such a device vs those that cannot afford them [1]. A suitable period of time would also be required to ensure that the proposed design of sensor could be accommodated within all the typical race walking footwear used by athletes. This may or may not require manufacturers to accommodate this in their production design and this may have a lead time, re-design or flexible introduction needed to accommodate this change ahead of major competitions and championships.

3.11. Resolving the dilemma

It is conceded here that the adoption of pragmatism does not provide outcomes that are free from criticism nor are absolute in nature. This same concern was highlighted previously in the aforementioned study that evaluated the use of Nike's advanced running footwear [10]. In the case of the application of the framework adopted in this paper, it is accepted that these could be seen as subjective, open to interpretation and may change as the introduction of SBS is formally incorporated by the sport. From the ten points, there were some concerns regarding:

- Access to the technology if required outside of competition by athletes who wish to train with SBS.
- Cost of the technology if required outside of competition by athletes who wish to train with SBS.
- A potentially disproportionate influence on an individual athlete's potential performance.
- Any grounds for increased injury due to any biomechanical changes caused by SBS adoption.
- A potential grounds for reskilling the sport as race walking technique is more reliably and consistently policed.

Conversely the potential benefits raised by the framework with the introduction of the technology are:

- Potentially increased spectator appeal
- An improved diagnosis of lifting.

The philosophical question that then arises is whether one or more of these five potentially negative factors are outweighed by those that do not, coupled with those that propose added benefits. The assumption that the SBS technology would possess the accuracy and precision that is required also needs to be taken into account.

It is proposed that issues surrounding access and cost are both factors that already exist in a similar fashion to other wearable technology that athletes use such as watches, GPS devices and heart rate monitors. Furthermore, any grounds for race walking re-skilling is only the result of technology regulating the sport to what is already intended to be achieved by its rules – i.e. the prevention of lifting. The ethos has therefore not changed so should not be seen as an issue. This merely leaves the concerns surrounding the disproportionate impact of the SBS and then any basis for injury as a result. The assumption of these could only be made via scientific inquiry but the assumption would be affected by the mass and placement of the SBS. It could be argued however that such variations already exist and are tolerated by the athlete with respect to their footwear choice. Therefore it is hypothesised that these remaining issues will not be significant to any magnitude beyond those that currently exist but that it would be prudent to ensure that the mass of the SBS should be minimised as much as possible. As a result, this paper would promote the view that SBS should be piloted for their efficacy. If such trials are then deemed successful, it is proposed that any arguments against SBS are not substantial enough when using the framework in this study to warrant their exclusion from competitive race walking use.

4. Conclusion

A framework that considers the implications of technology in competitive sport was applied to the potential adoption of foot-based sensors to help regulate legal gait in competitive race walking. Upon review, five points were identified that raised minor concerns of this technology's use. However, two potentially advantageous benefits were also highlighted. On balance, the negative issues were seen as minor in nature or had precedents for their dismissal. Provided scientific inquiry ascertains that such technology would not cause significantly disproportionate performance enhancement or injury, it is concluded that the introduction of such sensors would be appropriate for competitive race walking.

Author statement

We confirm that this article has not been published or is under consideration in another journal outlet, and that we will not submit this article to another journal. No potential conflict of interest was reported by the authors.

Data availability

No data was used for the research described in the article.

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