OMsignal Running Dynamics

Whitepaper by OMsignal
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***Abstract*—OM Running Dynamics are based on utilizing the accelerometer signal from the OMsignal box while users run. The OMsignal box is securely attached to the OMbra or OMshirt and measures electrocardiogram, breathing and acceleration. This document describes how the acceleration signal is used to obtain detailed information about a user's running technique. First, steady state running is identified and then the bio-mechanical metrics are calculated; temporal gait features, asymmetry, braking impulse, impact and vertical oscillation on each step. This document summarizes the metrics obtained via OMsignal Running Dynamics.**

Keywords*—*Biomechanics, Accelerometer, Bio-sensing Textile.

I. Introduction

Running is an easily accessible activity that can positive impact on peoples mental and physical health. However, due to the amount of impact that a runner absorbs over time there a risk of developing an injury due to too much running or poor running technique. In this paper, a method is presented to analyze running technique using the OMbra or the OMshirt.

II. Steady State Running

The first step in analyzing a user's running form is to determine when they are running in steady state. Steady state refers to periods of time when a runner is running at a relatively similar pace without any major changes in their pace, direction or running technique. Knowledge of when these steady state periods are occurring is important because most biomechanical based metrics should be considered for analysis only during steady state running periods. Inclusion of non-steady state data is likely to result in messy data that will be difficult to interpret due to the large variance in movement that can be performed during certain segments of the run. An example of this would be if a runner was running in a busy city and had to take a lot of sharp turns; we would not want to include this movement data in her analysis because it is not representative of her intrinsic movement technique. Table I summarizes the metrics that are obtained with OMsignal Running Dynamics.

TABLE I: OMsignal Running Dynamics Variable List

Variable	Details	Units
Temporal	Step time	sec
	Stride time	sec
	Air time	sec
	Ground contact time	sec
Asymmetry	Gait asymmetry	%
Impact		g
Braking impulse		m/s^3
Vertical oscillation		cm

III. Temporal Gait Parameters

Temporal gait parameters are based on foot strike and toe-off detection, which allow for calculation of step time, stride time, ground contact time and air time. These parameters in turn can be used to gain insight into a runners technique via the calculation of symmetry and movement variability. Figure 1 shows ground contact time over the course of a half marathon. This runner started out at a ninety minute pace, but then suffered a calf strain at 30 minutes into the run. He then finished the race at a slower pace and faded in the last fifteen minutes.

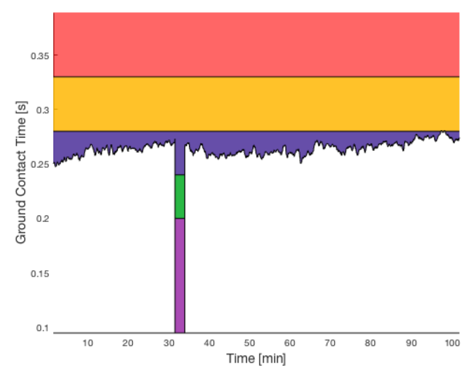


Fig. 1: Ground contact time calculated for each step over a full run. Average ground contact time is represented in the dashed horizontal line. Faster and more experienced runners will tend to have a shorter ground contact time, while slower, less experienced and taller runners will tend to have a longer ground contact time.

A. Validation

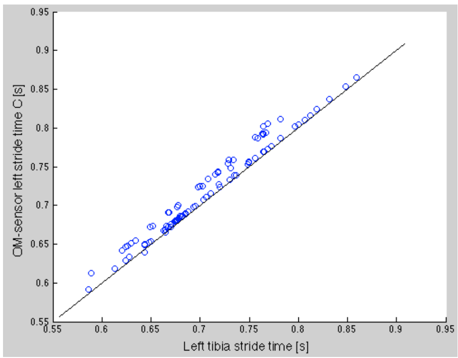
Stride time was validated with the use of inertial sensors secured to the anterior aspect of the lower shank on 28 participants. It has previously been shown that foot strike events can be accurately obtained from this location [4]. Table II summarizes the validation statistics and shows very high correlations between both measurement systems as well as relatively low confidence interval widths, indicating high levels of accuracy for the OMsignal measure. Figure 2 shows Bland-Altman [1] plots for the left stride time validation. Results for the right stride time validation were very similar, so have been left out of the current report for the sake of brevity.

IV. Asymmetry

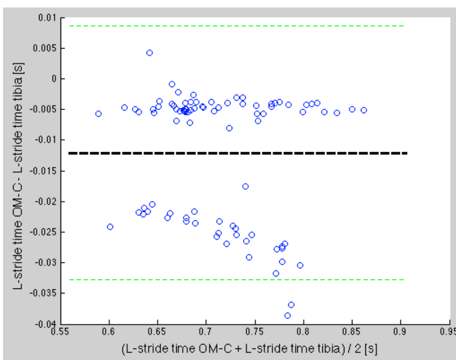
Asymmetry is based on comparing right-left step times. Some level of asymmetry will be acceptable among many

TABLE II: Stride time validation statistics.

	Mean diff	+95%CI	-95%CI	CIwidth	Corr	p-value
Units	sec	sec	sec	sec	*r*	
Stride time R	-0.0100	0.0092	-0.0292	0.0384	0.987	<0.000
Stride time L	-0.0121	0.0086	-0.0328	0.0414	0.985	<0.000
Combined				0.0399	0.986	



(a) Comparison of left stride time from OMsignal to stride as assessed from the shank sensor. The solid line has a slope of 1 and represents where each data point would fall if both systems perfectly agreed.



(b) Difference between stride time as calculated by OMsignal and the shank sensor plotted against the average of both measures.

Fig. 2: Bland-Altman validation plots for left stride time comparison between OMsignal results and results from a shank inertial sensor. Results are somewhat quantized due to the 50hz sampling rate of the OMsignal system, this was done to save battery, but can easily be increased to enhance resolution.

runners due to biomechanical features of their body. However, high levels of asymmetry in a new runner should be flagged, as well as increasing asymmetry development over time, which may be indicative of increasing injury risk. The OMsignal Running Dynamics asymmetry score is based on published research and uses the following formula [6]:

$$Asymmetry = 100 * \log(leftStepTime/rightStepTime)$$

Figure 3 shows symmetry scores from the same run shown in Figure 1. Prior to stopping, his asymmetry is low, but after he suffers the calf strain his asymmetry is increased. Symmetry is calculated in periods in which steady state running is detected.

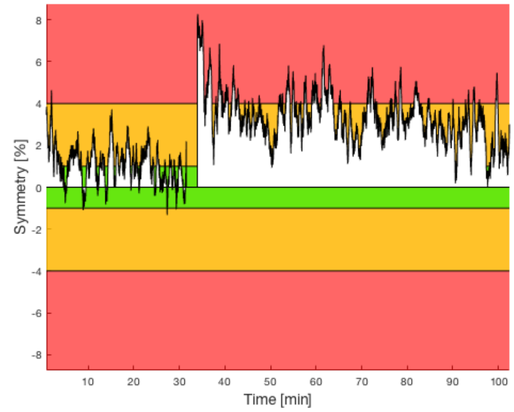


Fig. 3: Symmetry scores from a half marathon race in which the runner was on 90 minute pace for the first 30 minutes, then stopped with a calf strain. He then finished the race on the injured leg at a slower pace, eventually finishing in 104 minutes.

V. IMPACT

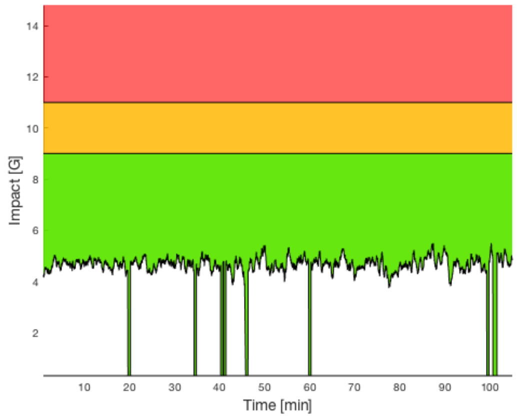
Tibial impact greater than 9G has been shown to increase risk of injury in runners [5] [2]. OMsignal designed a data set and used machine learning techniques to predict tibial impact from the OMsignal box on the OMbra or OMshirt. Impact increases with faster running speeds. High impactors may be encouraged to either slow down, or to increase their step rate by 7.5%, which has been shown to reduce impact [7].

Figure 4 compares impact levels over a run between an experienced runner with impact levels in a safe zone and an inexperienced runner with impact levels in a potentially dangerous zone. The increased loading on each step with the inexperienced runner could result in an overuse injury over time. Training this runner to decrease their impact could be done via a combination of live biofeedback while running as well as recommending exercise to encourage decreased impact forces at foot strike.

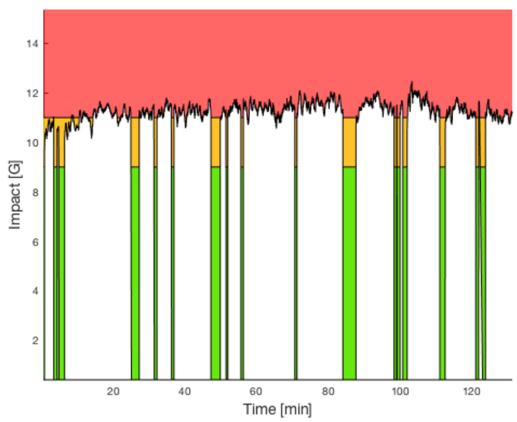
VI. BRAKING IMPULSE

Braking impulse is representative of how much a runner slows themselves down each time their foot hits the ground. An inefficient runner will contact the ground with her foot in front of her body and slow herself down significantly at the beginning of the ground contact phase. This means that the runner will be exposing themselves to more forces as well as using more energy than she should at a given speed. By contacting with the foot more below the body and initiating hip extension prior to foot strike, runners can decrease their braking impulse and reduce the amount of energy required to run at a given pace.

Figure 5 shows the categorization of *braking* within the OMrun data-set. In roughly 55% of runs, runners displayed levels of braking that coincide with efficient running mechanics. In just over 30% of the runs, runners displayed braking which may be indicative of poor running technique. Finally, in about 10% of runs, runners displayed high braking forces. Targeted interventions should be made to the high



(a) Experienced runner with impact levels in a safe zone.



(b) Inexperienced runner with higher impact levels which may increase his or her likelihood of suffering from an overuse injury.

Fig. 4: Impact levels from an experienced runner (a) and an inexperienced runner (b). The inexperienced runner may be at a higher risk of developing an over-use injury due to the elevated impact levels.

braking group to provide them with training and advice on how to reduce their braking impulse while running and achieve a more efficient running technique.

VII. Vertical Oscillation

Vertical oscillation is the distance that a runner moves vertically during each step. If a runner is moving too high during each step, then they are not running efficiently; they are directing too much energy into the vertical component of movement. This is a waste of energy and may be a factor in increasing impact levels at foot strike. These runners should undergo gait retraining in order to develop a safer, more efficient running technique. The vertical oscillation algorithm is based on a published methodology [3]. OMsignal vertical oscillation was compared to gold standard motion capture with participants running on a treadmill. It was found to be accurate (as shown in Figure 6).

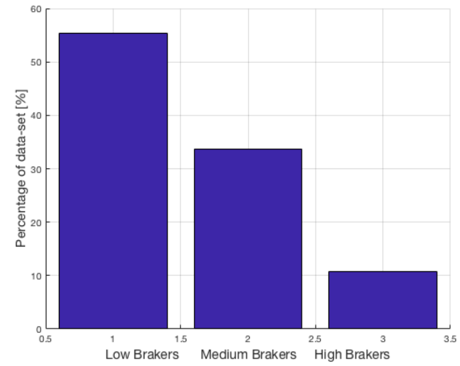
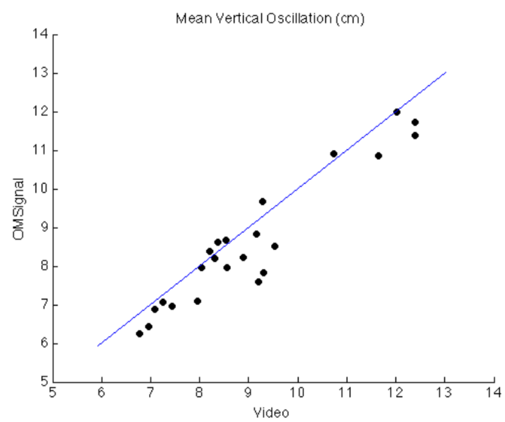
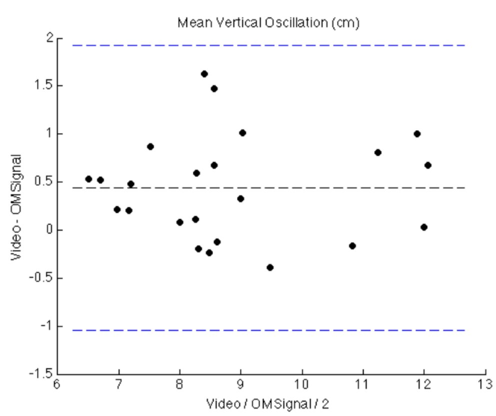


Fig. 5: Average braking values for all of the runs in the OMrun database. The majority of runs fall within the low (or efficient) category. Slightly more than 30% of the runs fall within the *medium* braking category and roughly 10% of runs have high braking values, which suggest inefficient running technique.



(a) Comparison of vertical oscillation from OMsignal Running Dynamics to vertical oscillation as assessed from motion capture. The solid line has a slope of 1 and represents where each data point would fall if both systems perfectly agreed.



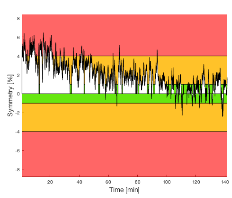
(b) Difference between vertical oscillation as calculated by OMsignal Running Dynamics and motion capture plotted against the average of both measures.

Fig. 6: Bland-Altman validation plots for vertical oscillation comparison between OMsignal results and results from motion capture.

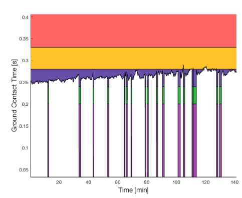
A. *Run-1*

Interpretation of these metrics should not occur in isolation, they should all be considered together when identifying areas of improvement for a runner. Figure 7 shows OMsignal Running Dynamics over the course of a 140 minute run for a recreational level runner. Over the course of the run the runner's symmetry improves, going from over 4% in the first 20 minutes until gradually settling into a more symmetrical zone for the last 40 minutes of the run. Perhaps at slower running speeds, or when he is not warmed up, he displays asymmetry. This might mean that a proper warm up is very important for this runner to ensure that they do not run with large asymmetries for long periods.

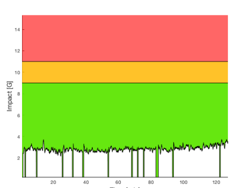
Ground contact time for this runner is in an average zone and it increases as the run goes on. Even, at the highest level it does not suggest that there is an issue with this runner's ground contact time values. Impact and braking decrease during the run. All impact levels are well below the threshold for injury development. Braking values start high for the first 20 minutes, but then decrease over the run into a safe level. The runner should be warned of potentially high braking values in the preliminary stage of this run. A slight increase in cadence could be a way for this runner to decrease his braking impulse and increase his running efficiency. Overall, this runner should be guided into undertaking a proper warm-up in order to achieve good running mechanics earlier in the run, rather than after 20 minutes, as was the case in the run shown in Figure 7.



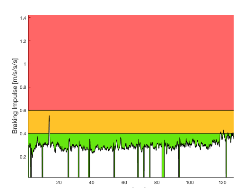
(a) Asymmetry



(b) Ground contact time



(c) Impact



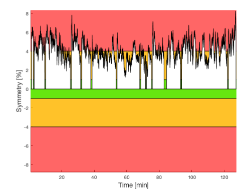
(d) Braking

Fig. 7: OMsignal Running Dynamics for a recreational runner completing a 2 hour and 20 minute training run.

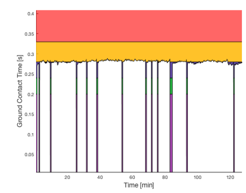
B. *Run-2*

Figure 8 shows an intermediate level runner performing a 2 hour training run. From (a) it can be seen that this runner consistently has longer stride times when pushing off the right leg. Their average symmetry is right on the border between yellow and red. A very slight improvement of symmetry would ensure that this runner has safe symmetry. Such an improvement may come about with more regular stretching or weekly yoga sessions. Ground contact time for this runner is very consistent across the run (b), however it is on the high side. It should be noted that this runner is 6 foot, 3 inches and longer ground contact times are associated with taller runners, so in the context of their height, this ground contact time is good.

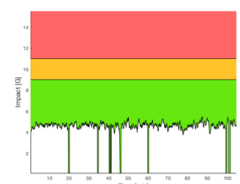
Section (c) in Figure 8 shows that this runner's impact is well within the safe zone for the entire run. Section (d) shows that his braking impulse is also well within the safe zone for the entire run. There is a very slight increase in impact and braking impulse at the end of the run, potentially due to fatigue and a deterioration in running form. This is not a major problem, but could be something for the runner to keep a watch out for on more fatiguing runs, as runners should decrease the amount of time they run with poor technique due to fatigue. There is a slight symmetry concern with this runner, but all other metrics look good.



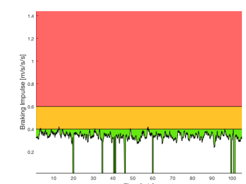
(a) Asymmetry



(b) Ground contact time



(c) Impact



(d) Braking

Fig. 8: OMsignal Running Dynamics for an intermediate level runner completing a 2 hour training run.

VIII. CONCLUSION

By combining the various metrics provided by the OMsignal Running Dynamics it is possible to get a detailed view of how an athlete is running over time and what area's they need to work on specifically to improve their running performance and as prevent injury.

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