DIFFERENCES IN TORSO KINEMATICS BETWEEN ERGOMETER CYCLING AND OUTDOOR CYCLING IN TRIATHLETES – A PRELIMINARY STUDY

Stuart A Evans[1], Daniel James[1], David Rowlands[2], James B Lee[1]

SABEL Labs, College of Health and Human Science, Charles Darwin University, Darwin, Australia[1]
School of Engineering, Griffith University, Nathan, Queensland, Australia[2]

ABSTRACT: Many triathletes cycle indoors when impacted by inclement road and weather conditions. In these situations, using a magnetic cycle ergometer (a turbo trainer) provides an alternative training solution. The purpose of this preliminary study was to investigate the biomechanical differences of torso kinematics during cycling on a magnetic turbo trainer compared with overground cycling. Triathletes (n=5) performed a varied 21 minute cycling cadence protocol in their familiar aerodynamic position on a magnetic resistance turbo trainer and a 21 minute overground cycle in their natural training environment whilst wearing a sacrum mounted triaxial accelerometer. Overground cycling significantly impacted anteroposterior torso kinematics ($f = 7.92$, $p<0.0001$) with extremely large effects observed (>0.9) compared to turbo cycling. Despite no significant difference in cumulative triaxial acceleration magnitudes ($p>0.05$), post-hoc analysis revealed significant variations when observed at each cadence change and epoch with increases to root mean square (RMS) values in overground cycling. Triathletes may need to consider torso position when cycling using different apparatus.

KEYWORDS: Wearables, Triathlon, Upper body, Cycling.

INTRODUCTION: Cycling can be performed on the road or indoors using stationary ergometers. In this regard, using different devices for cycling can form part of a structured training program to ensure fitness is preserved. The training required for the cycling component of triathlon typically necessitates the most time in both training and competitive environments given the length of the cycle discipline. Hence, triathletes regularly cycle in various settings in order to sustain training volume. Due to the large volume of training, many triathletes continue to train during the off season (i.e., the winter months). During this time, outdoor cycling may be limited by inclement weather conditions. A magnetic ergometer (a turbo trainer) provides an alternative training solution in these situations. A turbo trainer applies increased rolling resistance to replace the absent air resistance experienced during road cycling, while the cyclist maintains a stationary position (Arkestijn et al., 2013). Upper body (i.e., torso) position has been identified as an important parameter that can impact cycling performance. However, comparisons between road cycling using a freely moving bicycle suggest that a turbo trainer changes cycling technique. For instance, Bertucci et al. (2007) compared cycling on a Monark ergometer with road cycling and found that the stationary ergometer caused an altered distribution of power during the pedal revolution. Furthermore, a comparison between an electromagnetic turbo trainer and treadmill cycling demonstrated that overall muscle activity is higher when cycling on the turbo trainer (Duc et al., 2006).
A turbo trainer limits the cyclist to a predominately sagittal plane which may not necessitate active stabilisation of the torso. As cycling assessment is often confined to laboratories with participants typically cycling on ergometers, this does not always account for the changeable motion of the upper body that can occur in overground cycling. While laboratory systems provide accurate measurements, they classically deliver snippets of information, seldom allowing for constant analysis of prolonged cycling seen in training environments. Among the studies that use bicycle ergometers or similar devices, few concern the kinematics of the torso relative to cadence output. Moreover, limited investigations have compared torso motion by way of temporal acceleration magnitudes between cycling on a turbo trainer to overground cycling. Advances in small and precise inertial measurement units (IMU), in particular accelerometers, provide real-time detection of motion. Therefore, a preliminary study was

designed to quantify the magnitude of temporal torso kinematics using accelerometry in triathletes during cycling using a turbo trainer compared to overground cycling.

METHODS: Five triathletes from local triathlon clubs participated in this preliminary study (age: 31 ±8.8 yrs: body mass 77 ±8.5 kg: height 178 ±0.5.9 cm: weekly training volume: 8.7 ±3.71 hours) having given informed consent (approved by the University Research Ethics Committee: HREC 030317). The study analysed two cycling scenarios, namely cycling using a magnetic turbo trainer and cycling freely overground. In test one (day 1), participants cycled for a duration of 21 minutes at varied cadence performed on a magnetic resistance turbo trainer (Vulcan Magnetic Resistance Trainer). The trainer allowed participants to connect the rear wheel of their bicycle to a magnetic unit via a quick release skewer. All participants had prior experience of using a magnetic cycle trainer. In test two (day 2), participants cycled overground for a duration of 21 minutes at varied cadence. The two tests were separated by seven days. The route was an asphalt overground road loop that was 5.1 km in distance and included a minimum elevation of 3 m and a maximum elevation of 16 m. The average gradient was 0%. The magnetic trainer was positioned on the same route as test one (Figure 1).

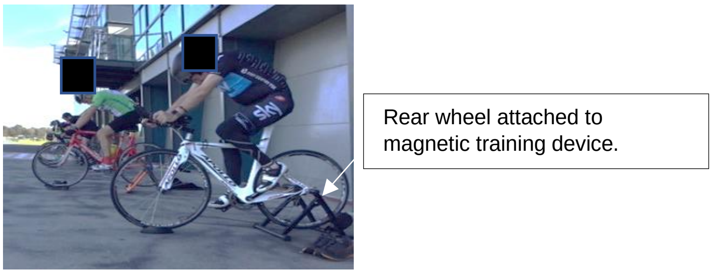

Figure 1. Participants cycling using a magnetic turbo trainer device.

For both tests, cadence order was controlled (i.e., not randomised) and systematically changed at 3 minute epochs with cadence quantified as individually preferred (IP) (rev/min^{1}), 55–60 (rev/min^{1}), 75–80 (rev/min^{1}) and 95–100 (rev/min^{1}) (Chapman et al., 2007). Cadence was selected due to its ease of measurement, participant familiarity and that all participants had fitted speedometers with cadence sensors on their bicycles. Cadence changes were verbally communicated by the authors with no further instructions provided. For both cycling tests participants were asked to maintain their familiar aerodynamic position. Prior to both tests, participants performed a 3 minute warmup of individually preferred cadence which was not recorded as part of the data analysis. Participants did not have bicycle configuration standardised as this would have affected muscle recruitment patterns (Bini & Hume, 2016). Participants conveyed exertion upon completion of each cadence condition and 3 minute interval using the Borg 6–20 ratings of perceived exertion (RPE) scale (Borg, 1988). Participants were requested to stay within ranges of 13–14 (defined as 'somewhat hard'). A Sportline 240 Econosport stopwatch (New York, NY, USA) was used to monitor time. In both tests, participants cycled in Northwave tri-sonic shoes (Northwave, Via Levada, Pederobba TV, Italy) with fitted Shimano SPD-SL pedals and yellow coded cleats with approximately 6° flotation and tension. To measure torso acceleration, a triaxial accelerometer was used (52 mm x 30 mm x 12 mm, mass 23 g; resolution 16-bit, full-scale range 16 *g,* 100 Hz sample rate, SABEL Labs, Darwin, Australia). This accelerometer allows for a time series of data to be stored in its memory. The accelerometer was able to provide data on torso kinematics along three axes, namely: longitudinal (x, LN), mediolateral (y, ML) and anteroposterior (z, AP). The accelerometer was secured to participants by double sided tape between the L5 and S1 spinous process in order to examine movement at the closest external point to the body centre of mass (COM) (Lee et al., 2010). This allowed participants to cycle freely overground and outside of the traditional laboratory environment. The accelerometer was controlled wirelessly from the principal author via a typical Hewlett Packard PC using a MATLAB Toolkit. In practical terms, only the local acceleration components of the triathlete were analysed. For repeatability of measurement, the same sensor and cycle protocol was used in both tests. When a change of cadence was required, the accelerometer was wirelessly synchronised in order to identify the relative epoch in the raw data. In a performance context, if one test results in less torso acceleration triathletes will entail less overall torso motion. For each cadence condition, the mean torso acceleration magnitude for each axis was determined over the 3 minute epoch. Raw sensor data was scaled into metres per second/per second (m/s^2). Means and standard deviation (±SD) were analysed for the local acceleration components. A repeated measures ANOVA was used to evaluate the standardised mean difference between individual accelerometric axis in turbo cycling and overground cycling. These values were then applied to obtain the correlation coefficient (r) as an effect size (ES), classified as 0.1-0.3 (small), >0.3-0.5 (moderate), >0.5-0.7 (large), >0.7-0.9 (very large) and >0.9 (extremely large) (Hopkins et al., 2009). The root mean square (RMS) values in the three sensing axes were used to calculate RMS proportional deviations from turbo and overground cycling per cadence-epoch. An alpha (α) level set at 5% was used to compare acceleration in three orthogonal axes between tests.

RESULTS: Although there was no significant difference in cumulative temporal triaxial acceleration magnitudes ($p>0.05$), analysis of each cadence and associated epoch revealed differences between the two cycling conditions. In particular, overground cycling significantly impacted anteroposterior torso acceleration ($f = 7.92$, $p<0.0001$) with extremely large effects observed (>0.9) compared to turbo trainer cycling (Table 1, Figure 2a). Overall RMS was higher per cadence-epoch in overground cycling.

Table 1. Triaxial torso accelerations during turbo and overground cycling. Values expressed as mean acceleration in m/s^2

Axis	Turbo	Over	Turbo	Over	Turbo	Over	Turbo	Over	Turbo	Over	Turbo	Over
	3–6 mins[1]		6–9 mins[1]		9–12 mins[1]		12–15 mins[1]		15–18 mins[1]		18–21 mins[1]	
LN (x) m/s^2	7.72	8.95	7.62	8.23	7.62	7.74	7.41	7.92	7.46	8.04	6.20	7.59[d]
ML (y) m/s^2	0.02	-0.58	-0.03	0.04	0.01	0.11	-0.00	0.11	0.03	0.19	0.03	0.16
AP (z) m/s^2	-4.00	-5.51*[d]	-5.05	-5.75*[d]	-5.64	-5.92*[d]	-5.79	-6.05*[d]	-5.45	-5.99*[d]	-3.63	-5.74*[d]
RPE	8	8	9	10	9	10	9	11	10	12	11	13
RMS	5.02	5.67	5.28	5.57	5.57	5.62	5.43	5.66	5.33	5.61	4.12	4.85

* Turbo = turbo trainer cycling; over = overground cycling. RMS = root mean square; RPE=ratings of perceived exertion. *denotes statistically significant from turbo cycling. [d]denotes ES >0.7-0.9

Comparisons between longitudinal and anteroposterior acceleration magnitudes revealed significant differences (Figure 2b).

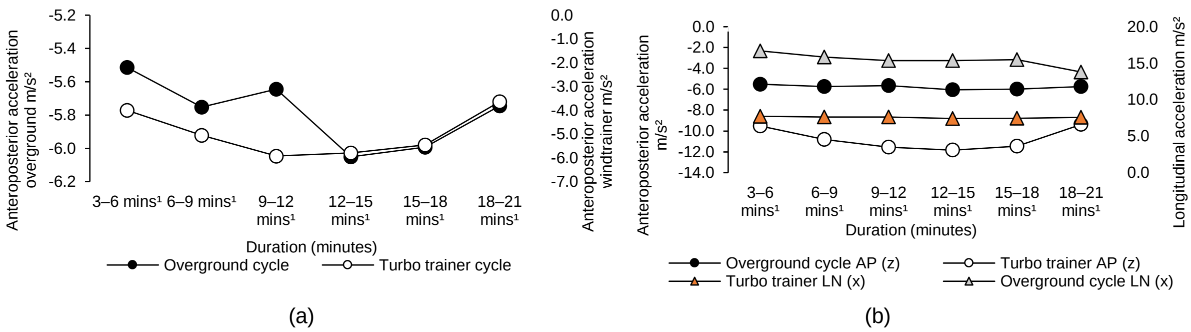

Figure 2. (a) Temporal anteroposterior (AP) accelerations of the torso during turbo and overground cycling; (b) Temporal anteroposterior (AP) and longitudinal (LN) accelerations of the torso during turbo and overground cycling

No difference between longitudinal ($f = 0.57$, $p>0.05$) or mediolateral torso acceleration ($f = 0.10$, $p>0.05$) was detected between tests despite a moderate effect (>0.3) observed in temporal longitudinal torso acceleration.

DISCUSSION: This preliminary study compared temporal torso kinematics between cycling using a turbo trainer and overground cycling and showed that significant differences and very large effects occurred in the anteroposterior direction (Table 1). Despite no significant

differences to longitudinal and mediolateral torso kinematics, as cadence, and therefore the amount of work done, were controlled between cycling tests the effects of possible fatigue as inferred by ratings of perceived exertion (RPE) results are considered negligible. As cadence was varied to reflect a typical training situation, the increase in temporal anteroposterior torso motion in overground cycling could be due to an increase in gross motion by the triathletes (Figure 2). It is known that an increase in workload increases the application of the force to the saddle (Stone & Hull, 1995) whilst torso accelerations increase (Costes et al., 2015). In this instance as cadence increased it is feasible that torso motion likewise increased. Although torso acceleration served as a proxy for body acceleration, the accelerometer was mounted such that the longitudinal axis moves along the sagittal plane. Nevertheless, the limb's position relative to the body and the body's acceleration are possibly reflected by increased propulsion and braking in overground cycling which would increase anteroposterior torso motion.
Torso angle affects leg kinematics as a forward shift of the body COM means that the cyclist's body is less maintained by the saddle (Rannama et al., 2017). Results from the current study is analogous to this statement as a larger forward shift of the torso during overground cycling would feasibly accelerate the COM when breaking or changing cadence. In this instance, both longitudinal and anteroposterior acceleration would conceivably increase in magnitude (Figure 2). This suggests some triathletes experience difficulty controlling the rhythmic displacements of the torso when cycling overground. Despite no significant differences to mediolateral torso acceleration, greater magnitudes occurred in overground cycling. Whilst this result may not be unexpected given the unpredictability of overground cycling, this study shows that differences between upper body anteroposterior motion exists. This may have performance implications as excessive upper body motion may be disadvantageous when cycling for prolonged durations.

CONCLUSION: Based on the results of this study, overground cycling may increase the magnitudes of anteroposterior acceleration magnitude of the torso compared to cycling on a turbo trainer. Outcomes from this research provide indications to coaches and triathletes that there is a need to further investigate the effects of torso acceleration when cycling using different devices in order to monitor performance.

REFERENCES

Arkesteijn M et al. (2013). The effect of turbo trainer cycling on pedalling technique and cycling efficiency. *Int J Sports Med*, 34, 520–525.

Bertucci, W., Grappe, F., & Groslambert, A. (2007). Laboratory versus outdoor cycling conditions: differences in pedalling biomechanics. *Journal of Applied Biomechanics,* 23, 87–92.

Bini, R.R., & Hume, P.A. (2016). A Comparison of static and dynamic measures of lower limb joint angles in cycling: application to bicycle fitting. *Human Movement*, *17*(1), 36–42.

Borg, G. (1998). Borg's perceived exertion and pain scales. *Human Kinetics*.

Chapman, A.R., Vicenzino, B., & Hodges, P.W. (2007). A protocol for measuring the direct effect of cycling on neuromuscular control of running in triathletes, *Journal of Sports Science,* 27, 767–782.

Costes, A., Turpin, N. A., Villeger, D., Moretto, P., & Watier, B. (2015). A reduction of the saddle vertical force triggers the sit–stand transition in cycling. *Journal of biomechanics*, 48, 2998–3003.

Duc, S., Bouteille, T., Bertucci, W., & Grappe, F. (2006). Comparison of the EMG activity of pedaling between an exercise performed on a stationary ergometer and on a motorized treadmill. *Journal of Sci and Sports*, 21, 309–31.

Hopkins, W., Marshall, S., Batterham, A., & Juri Hanin. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*(1), 3–13.

Lee, J., Mellifont, R., & Burkett, B. (2010) The use of a single inertial sensor to identify stride, step, and stance durations of running gait. *Journal of Science and Medicine in Sport,*13, 559–563

Rannama, I., Pedak, K., Bazanov, B., & Port, K. (2017). Cycling specific postural stability during incremental exercise: The relationship with cyclists functional movement screen score. *Journal of Human Sport and Exercise*, *12*(1), 83–95.

Stone, C., & Hull, M.L. (1995). The effect of rider weight on rider-induced loads during common cycling situations. *Journal of Biomechanics*, 28, 365–375.