A systematic review and meta-analysis of cross-over studies comparing physiological, perceptual and performance measures between treadmill and overground running

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**Authors:** Jayme R. Miller¹, Bas Van Hooren²,³ (ORCID 0000-0001-8163-693X), Chris Bishop¹,⁴ (ORCID 0000-0002-1251-8785), Jonathan D. Buckley¹ (ORCID 0000-0003-0298-2186), Richard W. Willy⁵ (ORCID 0000-0002-1249-228X), Joel T. Fuller⁶ (ORCID 0000-0002-0997-4878)

**Affiliations:**

1. Alliance for Research in Exercise, Nutrition and Activity (ARENA), School of Health Sciences, University of South Australia, Adelaide 5001, SA, Australia.
2. NUTRIM School of Nutrition and Translational Research in Metabolism, Maastricht University Medical Centre+, Department of Nutrition and Movement Sciences, Maastricht, The Netherlands.
4. The Biomechanics Lab, Adelaide, SA, Australia.
5. School of Physical Therapy and Rehabilitation Sciences, University of Montana, Missoula, MT, USA.
6. Faculty of Medicine and Health Sciences, Macquarie University, NSW, Australia.

**Corresponding author:** Joel T. Fuller; joel.fuller@mq.edu.au
Non-Motorised Treadmill Studies

1. Oxygen uptake

Pooled results indicated that submaximal non-motorised treadmill running increased oxygen uptake (\(\dot{V}O_2\)) by 13.69 ml/kg/min compared to overground (Fig. 1). This difference was significant (\(P<0.001; \, n=24; \, k=2\)) but was affected by high heterogeneity (\(I^2=75\%\)) and provided low Grading of Recommendations Assessment, Development and Evaluation (GRADE) quality of evidence (Table 1).

![Fig. 1 Random-effects meta-analysis of submaximal oxygen uptake during non-motorised treadmill compared to overground running. CI, confidence interval; MD, mean difference; N, sample size. * Mean submaximal running speed used in study.](image)

Pooled results indicated that non-motorised treadmill running increased \(\dot{V}O_2\) compared to overground by 9.70 ml/kg/min for near-maximal running (Fig. 2). This difference was significant (\(P=0.001; \, n=24; \, k=2\)) but was affected by high heterogeneity (\(I^2=69\%\)) and provided low GRADE quality of evidence (Table 1).
Fig. 2 Random-effects meta-analysis of near-maximal (≥80% VO₂max) and maximal oxygen uptake during non-motorised treadmill compared to overground running. CI, confidence interval; MD, mean difference; N, sample size.

Results from one study, involving 10 runners, indicated that mean VO₂ during a 5 km time trial was not significantly different between non-motorised treadmill and overground running (standardised mean difference (SMD): 0.48) (Stevens et al. 2015).

2. Heart rate

Pooled results indicated that submaximal non-motorised treadmill running increased heart rate (HR) by 31 bpm (Fig. 3). This difference was significant (P<0.001; n=24; k=2) but was affected by high heterogeneity (I²=54%) and provided low GRADE quality of evidence (Table 1).
Fig. 3 Random-effects meta-analysis of submaximal heart rate during non-motorised treadmill compared to overground running. CI, confidence interval; MD, mean difference; N, sample size. * Mean submaximal running speed used in study.

Pooled results indicated that non-motorised treadmill running increased HR compared to overground by 21 bpm for near-maximal running (Fig. 4). This difference was significant ($P<0.001$; $n=24$; $k=2$) but was affected by high heterogeneity ($I^2=96\%$) and provided low GRADE quality of evidence (Table 1).

Fig. 4 Random-effects meta-analysis of near-maximal ($\geq 80\% \dot{V}O_2\text{max}$) and maximal heart rate during non-motorised treadmill compared to overground running. CI, confidence interval; MD, mean difference; N, sample size.

Results from one study, involving 10 runners, indicated that mean HR during a 5 km time trial was not significantly different between non-motorised treadmill and overground running (SMD: <0.01) (Stevens et al. 2015).

3. Blood lactate concentration

Results from one study, involving 9 runners and 1 cross country skier, indicated that non-motorised treadmill running (12 and 14 km/h) with 1% grade was associated with moderate to very-large increases in blood lactate concentration compared to overground running at submaximal (SMD range: 0.96-2.18) and near-maximal/maximal (SMD: 4.19) intensities (Wee
et al. 2016). Results from one study, involving 10 runners, indicated that blood lactate concentration at the end of a 5 km time trial was significantly greater for non-motorised treadmill compared to overground running (SMD: 0.74) (Stevens et al. 2015).

4. Rating of perceived exertion

Pooled results indicated that submaximal non-motorised treadmill running caused a large increase in rating of perceived exertion (RPE) (equivalent to a 3-point increase on 6-20 scale) (Fig. 5). This difference was not significant ($P=0.117; n=24; k=2$), was affected by high heterogeneity ($I^2=97\%$) and provided low GRADE quality of evidence (Table 1).

![Fig. 5 Random-effects meta-analysis of submaximal rating of perceived exertion during non-motorised treadmill compared to overground running. CI, confidence interval; MD, mean difference; N, sample size. * Mean submaximal running speed used in study.](image)

Pooled results indicated that near-maximal ($\geq80\% \text{VO}_{2\text{max}}$) non-motorised treadmill running increased RPE by 4.0 units on the 6-20 scale (Fig. 6). This difference was statistically significant ($P<0.001; n=24; k=2$), was affected by high statistical heterogeneity ($I^2=85\%$) and provided low GRADE quality of evidence (Table 1).
Fig. 6 Random-effects meta-analysis of near-maximal (≥80% $\overline{VO}_2$max) and maximal rating of perceived exertion during non-motorised treadmill compared to overground running. CI, confidence interval; MD, mean difference; N, sample size.

Results from one study, involving 10 runners, indicated that mean 0-10 scale RPE during a 5 km time trial was significantly greater for non-motorised treadmill compared to overground running (SMD: 0.41) (Stevens et al. 2015).

5. **Endurance performance**

Results from one study, involving 10 runners, indicated that mean 5 km time trial performance time was significantly worse for non-motorised treadmill compared to overground running (SMD: 2.19) (Stevens et al. 2015).

6. **Discussion**

Only three studies compared physiological and perceptual outcomes between non-motorised treadmill and overground running. In contrast to the findings related to motorised treadmills, submaximal and near-maximal running on a non-motorised treadmill was associated with substantially higher $\overline{VO}_2$ (≥9.70 ml/kg/min higher), HR (≥21 bpm higher), and RPE (SMD ≥1.54) compared to overground. Additionally, blood lactate concentrations were substantially higher (SMD range: 0.74-2.18) (Wee et al. 2016; Stevens et al. 2015) and 5 km time trial performance was substantially poorer (SMD: 2.19) (Stevens et al. 2015) during non-motorised running.
treadmill compared to overground running. As a result, non-motorised treadmill running should not be used to match the physiological and perceptual demands of overground running. Instead, non-motorised treadmills may have applications as a training modality that is associated with high physiological and perceptual effort and in situations where instantaneous changes in running speed are required — a situation that is challenging to replicate on a motorised treadmill.
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CI, confidence interval; GRADE, Grading of Recommendations Assessment, Development and Evaluation; HR, heart rate; k, number of independent studies; MD, mean difference; n, number of participants; RPE, rating of perceived exertion; SMD, standardised mean difference; VO₂, oxygen uptake.
References

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