Physiologic Responses to Running with a Jogging Stroller

Authors D. A. Gregory[1], K. A. Pfeiffer[2], K. E. Vickers[1], A. J. Aubrey[2], J. I. Flynn[1], C. P. Connolly[1], D. P. Coe[1]

Affiliations [1] University of Tennessee, Kinesiology, Recreation, and Sport Studies Knoxville, United States
[2] Michigan State University, Kinesiology, East Lansing, United States

Key words
- oxygen consumption (VO_2)
- heart rate
- rating of perceived exertion (RPE)
- field trials

Abstract

The purpose of this study was to assess the effect of running with a jogging stroller (JS) on oxygen consumption (VO_2), heart rate (HR), and rating of perceived exertion (RPE). This study included 2 parts: Part 1 involved participants (N = 15) running on an indoor track and Part 2 involved participants (N = 12) running on a paved greenway. All participants completed 6, one-mile trials randomized over 2 visits: 3 were completed at a predetermined pace (160.8 m·min^{-1}) without a JS (NoJS), with 11.36 kg in the JS (JS1), and 22.72 kg in the JS (JS2) and 3 were self-paced and included NoJS, JS1, and JS2. VO_2 and HR were measured using a portable metabolic system and telemetry. Repeated measures ANOVAs were used to determine differences among conditions. Part 1, there were no differences in VO_2 across conditions, but HR and RPE were significantly higher ($P < 0.05$) during the JS trials compared to the NoJS trials. Part 2, VO_2 and RPE during JS trials were higher than NoJS trials ($P < 0.05$). No significant differences were found in HR. The results indicate that it is feasible to run while pushing a JS with minimal increases in exertion compared to running without a JS.

Introduction

Jogging strollers are commonly used by women and men who want to exercise and spend quality time with their children while exposing them to a healthy, active lifestyle. Jogging strollers are manufactured to allow parents to push their children while walking, jogging, or running. It has been well established that pushing, pulling, and carrying an external load will alter oxygen consumption (VO_2), heart rate (HR), and rating of perceived exertion (RPE) [3, 6, 8, 10–12, 14]. A study conducted by Garcin et al. [7] found that pushing and hauling (i.e., pulling) a load while on a treadmill significantly increased VO_2, HR, and RPE in both sedentary and endurance trained individuals. The researchers also concluded that pushing an external load was more strenuous than hauling. However, very little research has specifically examined the impact that jogging stroller use has on various physiological variables.

Results from the limited number of studies examining physiological characteristics while pushing jogging strollers are varied. Smith et al. [16] found no significant difference in VO_2 when running with and without a jogging stroller, but did find a significant increase in HR, lactate concentration, ventilation, and RPE when participants ran with the jogging stroller. Brown et al. [4] found a significant increase in VO_2 (~4 ml·kg^{-1}·min^{-1}) and HR (~6 beats·min^{-1}) when using a jogging stroller. However, no difference in RPE was observed. Both of these studies included participants who had no previous experience using a jogging stroller. Smith et al. [16] did not allow any familiarization time with the jogging stroller, while Brown et al. [4] had participants practice with the jogging stroller on 2–3 occasions prior to testing. Smith et al. [16] also used an oval, all-weather track for the trials. These methodological differences may be partially responsible for the mixed results found in previous studies. Accordingly, this study aimed to address previous limitations by assessing recreational runners who were accustomed to running with jogging strollers. The protocol included use of an oval, indoor track and a paved urban greenway for the running trials. This methodology allowed for the replications of previous studies as well as the simulation of a free-living, natural environment. Thus, the purpose of this study was to assess the effect of running with a jogging stroller on VO_2, HR, and RPE compared to running without a jogging stroller on a track (Part 1) and on a paved, urban greenway (Part 2).

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Correspondence
Dr. Dawn Podulka Coe, PhD
University of Tennessee
Kinesiology, Recreation, and Sport Studies
1914 Andy Holt Avenue
37996 Knoxville
United States
Tel.: +1/865/974 0294
Fax: +1/865/974 8981
dcoe@utk.edu

Methods

Participants
2 different sets of participants were recruited to participate in Parts 1 and 2 of this study. 15 recreational runners volunteered to participate in Part 1 of the study, and an additional 12 recreational runners volunteered to participate in Part 2. To be included in either part of the study, participants had to be between the ages of 18 and 44, have no more than one risk factor for cardiovascular disease determined using American College of Sports Medicine (ACSM) criteria [2], have no pre-existing diseases, and run at least 1 day a week for 2 consecutive miles while pushing a jogging stroller. Participants were excluded if they were pregnant, had any current musculoskeletal injuries that limited running ability, or had 2 or more risk factors for cardiovascular disease using ACSM criteria [2]. In general, the participants had no more than one risk factor for cardiovascular disease, with the most common risk factor being a positive family history. None of the participants had pre-existing cardiovascular disease, and none of them were taking medications that would affect the physiological variables of interest. All participant ran at least 2 miles 1 day per week using a jogging stroller, and the majority exercised at least 5 times per week. Participants were recruited via flyers posted at area businesses, postings on local internet message boards, emails to list serves, and word of mouth. Prior to the participants' initial visit, a screening interview was conducted by telephone to determine eligibility. If eligible, participants were instructed to report to the laboratory where all procedures were explained, and the participants' questions were answered. All participants signed an informed consent form before participating in the study. This study was approved by the University of Tennessee Institutional Review Board, the Michigan State University Biomedical and Health Institutional Review Board, and the Grand Valley State University Human Research Review Committee and meets the ethical standards of the International Journal of Sports Medicine [9].

Anthropometrics
Height was measured in centimeters using a portable stadiometer (SECA, Hamburg, Germany) and mass was measured in kilograms using a calibrated, digital scale (LifeSource ProFIT, A&D Medical, Milpitas, CA). All measurements were taken prior to metabolic testing with the participant wearing light clothing and socks, using standard procedures [13]. Mass was also measured while wearing shoes and the portable metabolic system in order to factor in the mass of these items on metabolic variables. Body Mass Index (BMI) was calculated as body mass (kg) divided by height (m) squared.

Fitness testing
Each participant completed a graded exercise test on a treadmill prior to completing any field testing. For Parts 1 and 2 of the study, peak oxygen consumption (VO_{2peak}) was measured using the Oxycon Mobile portable metabolic system (CareFusion, Yorba Linda, CA). Validity of the Oxycon Mobile metabolic system has been reported [15]. The metabolic system was calibrated according to manufacturer guidelines prior to testing each participant. HR was measured using telemetry (Polar, Lake Success, NY). Participants rested in a seated position for 5 min, and pre-exercise heart rate and blood pressure were obtained. Blood pressure was measured using a validated, automated blood pressure monitor (OMRON, Vernon Hills, IL). Participants were given adequate time to warm-up and stretch before performing the graded exercise test. The warm-up was completed based on participants' preferences. The treadmill protocol began at 67 m·min^{-1} and increased 13.4 m·min^{-1} every minute until 160.8 m·min^{-1} was obtained. After 160.8 m·min^{-1} was reached, speed was held constant and incline was increased by 3 % every minute until volitional exhaustion. RPE was also recorded at the end of every stage using the OMNI RPE scale [17]. VO_2 and HR were averaged over 30-s intervals and the highest oxygen consumption achieved was recorded as the VO_{2peak}.

Field testing
Jogging stroller and set-up
A Baby Jogger Performance Series (Baby Jogger Co., Richmond, VA) single jogging stroller was used by each of the participants in Parts 1 and 2 of the study. This jogging stroller is constructed from a lightweight aluminum, weighs 9.68 kg, is aerodynamic, has 16 inch wheels, and includes a shock absorption system. Weight plates, 11.36 kg and/or 22.72 kg, were securely strapped into the jogging stroller for each of the trials. These weights were chosen to simulate running with an average sized toddler (11.36 kg) or with a toddler and an infant (22.72 kg).

Field trials
For parts 1 and 2 of the study, field trials consisted of 6, one-mile trials spread over 2 visits (3 trials were completed at each visit). 3 trials involved the participant jogging at a 160.8 m·min^{-1} pace (1) without the jogging stroller (NoJS), (2) with 11.36 kg in the jogging stroller (JS1), and (3) with 22.72 kg in the jogging stroller (JS2). The other 3 trials consisted of the participant jogging at a self-selected pace (1) without the jogging stroller (NoJS), (2) with 11.36 kg in the jogging stroller (JS1), and (3) with 22.72 kg in the jogging stroller (JS2). The self-selected pace, typically faster than the 160.8 m·min^{-1} pace [average speed: 198.3 m·min^{-1} (Part 1) and 182.2 m·min^{-1} (Part 2)], was added to replicate the participants' experience when running with the jogging stroller. Participants were instructed to run their typical pace when running with a jogging stroller in order to determine the first self-selected pace trial. The remaining 2 self-selected pace trials were yoked to the first trial and participants maintained the same pace regardless of condition (i. e., no jogging stroller or one of the weighted jogging stroller trials). The order of the 6 trials was randomized for each participant. An illustration of these trials can be found in ▶ **Table 1**.

Part 1 – Indoor track
Field trials for site 1 consisted of 6, one-mile trials on a 400 m, oval indoor track. 3 trials were completed during visit #2 and 3 trials during visit #3. The order of the trials was randomized. Participants rested in between trials until HR was within 5 beats of the pre-exercise HR, which was measured at the beginning of visits #2 and 3. Participants were given ample time to stretch and warm-up before completing the trials. 2 researchers located

Table 1 Description of field trials.

160.8 m·min^{-1} pace	Self-paced mile
without jogging stroller (NoJS)	without jogging stroller (NoJS)
with jogging stroller – 11.36 kg (JS1)	with jogging stroller – 11.36 kg (JS1)
with jogging stroller – 22.72 kg (JS2)	with jogging stroller – 22.72 kg (JS2)

Part 1 took place on an indoor track; part 2 took place on an outdoor greenway at either end of the track were responsible for pacing the participants through all of the trials.

VO_2 and HR were measured continuously using the Oxycon Mobile portable metabolic system and telemetry. Prior to the first trial of each visit, mass was measured at the field test site while wearing shoes and the portable metabolic system. For each one-mile trial, participants were instructed to run 4 laps around the track. Research assistants monitored the pace of the participants using stopwatches and markers placed on the track and periodically instructed the participants to either speed up or slow down based on the pace they were running. Immediately following each trial, participants verbally indicated their RPE. VO_2 and HR were averaged over 30-s intervals and steady-state values were used in the data analysis.

Part 2 – Outdoor greenway

Field trials for site 2 consisted of 6, one-mile trials on a paved, urban greenway. The greenway is widely used by recreational runners, walkers, and cyclists. It is relatively flat with little incline or decline. The same greenway course was used for all trials for participants enrolled in this part of the study (participants were different than those who completed Part 1). 3 trials were completed during visit #2 and 3 trials during visit #3. The 6 trials were randomized for each of the participants. Participants rested in between trials until HR was within 5 beats of the pre-exercise HR, which was measured at the beginning of visits #2 and 3. Participants were fit with a Garmin Forerunner 405 GPS fitness watch (Garmin, Olathe, KS) to aid in their ability to maintain the 160.8 m·min^{-1} and self-selected paces, as well as to accurately measure the distance covered during each trial. Participants were instructed to periodically check their pace using the Garmin fitness watch and to either speed up or slow down in order to maintain their given pace.

VO_2 and HR were measured continuously using the Oxycon Mobile portable metabolic system and telemetry. Prior to the first trial of each visit, mass was measured at the field test site while wearing shoes and the portable metabolic system. For each one-mile trial, participants were instructed to run one mile on the greenway, more specifically, they ran a half of a mile out and then ran a half of a mile back using the Garmin GPS fitness watch to maintain their pace. Immediately following each trial, participants verbally indicated their RPE. VO_2 and HR were averaged over 30-s intervals and steady-state values were used in the data analysis.

Statistical analysis

One-way, repeated measures ANOVAs were used to determine whether there were significant differences among the 3 conditions (without the jogging stroller, with 11.36 kg in the jogging stroller, and with 22.72 kg in the jogging stroller) for VO_2, energy expenditure (Kcal·min^{-1}), respiratory exchange ratio (RER), percent of VO_{2peak} (%VO_{2peak}), minute ventilation (V_E), HR, and RPE at 160.8 m·min^{-1} and self-selected paces for Parts 1 and 2 of the study. When significant differences were found, paired sample t-tests were run with a Bonferroni adjustment to determine where the significant differences among the conditions occurred. Statistical significance was set at $P<0.05$. SPSS (version 17.0) was used for all statistical analysis.

Results

The descriptive characteristics of the participants in the each study can be found in **Table 2**. The BMI of our participants was below the median for men and women according to the most recent U.S. statistics [5], indicating that on average the participants were characterized as healthy by BMI standards. Participants' VO_{2peak} ranked above the 90th percentile for individuals in their age range [2]. There were no significant differences among characteristics between the participants in the 2 studies.

Part 1 – Indoor track

For the 160.8 m·min^{-1} trial on the indoor track, there were no significant differences for VO_2, energy expenditure (Kcal·min^{-1}), RER, and %VO_{2peak} among trials (**Table 3**). There was a significant difference in HR between JS1 and JS2 ($P<0.05$). RPE was significantly higher for JS2 compared to NoJS ($P<0.05$). V_E was significantly greater for JS1 than NoJS ($P<0.05$). When examining the effect of the jogging stroller on the metabolic and physiologic variables for the self-paced trials, the only significant difference observed across conditions was V_E was greater in the JS1 condition compared to NoJS (**Table 3**).

Table 2 Participant characteristics (Mean ± SD, %).

Variables	Part 1 (N = 15)	Part 2 (N = 12)
age (years)	33.7 ± 3.1	34.5 ± 5.4
sex (%)	40 % male 60 % female	25 % male 75 % female
height (m)	1.69 ± 0.08	1.71 ± 0.08
weight (kg)	67.8 ± 12.4	70.8 ± 10.6
body mass index (BMI; kg/m^2)	23.8 ± 2.9	24.1 ± 2.2
VO_{2max} (ml/kg/min)	49.3 ± 7.2	52.8 ± 8.4

Table 3 Physiologic variables running with and without a jogging stroller on an indoor track (Mean ± SD).

	160.8 m·min^{-1} (N = 15)			Self-paced (N = 15)		
variables	**NoJS**	**JS1**	**JS2**	**NoJS**	**JS1**	**JS2**
VO_2 (ml·kg^{-1}·min^{-1})	31.3 ± 3.7	31.3 ± 3.4	31.3 ± 3.4	36.1 ± 5.1	37.5 ± 4.8	37.2 ± 6.2
energy expenditure (Kcal·min^{-1})	10.5 ± 1.6	10.5 ± 1.6	11.1 ± 2.2	12.1 ± 2.6	12.7 ± 2.7	12.5 ± 2.7
respiratory exchange ratio	0.90 ± 0.1	0.91 ± 0.1	0.90 ± 0.1	0.99 ± 0.1	0.97 ± 0.1	0.98 ± 0.1
% VO_{2peak}	64.6 ± 11.8	64.8 ± 11.8	67.8 ± 9.8	73.5 ± 11.6	76.9 ± 11.2	76.1 ± 13.3
V_E (L·min^{-1})	53.7 ± 8.9	**55.6 ± 10.7^c**	65.6 ± 26.5	70.3 ± 20.6	**74.8 ± 19.4^c**	73.4 ± 19.0
HR (beats·min^{-1})	148 ± 13	149 ± 15	**154 ± 14^a**	163 ± 16	166 ± 16	166 ± 20
RPE	3.8 ± 1.8	4.3 ± 1.6	**4.9 ± 1.5^b**	5.3 ± 1.3	6.1 ± 1.2	6.1 ± 1.8

a) JS2 significantly higher than JS1 ($P<0.05$)
b) JS2 significantly higher than NoJS ($P<0.05$)
c) JS1 significantly higher than NoJS ($P<0.05$)

Table 4 Physiologic variables running with and without a jogging stroller on a greenway (Mean ± SD).

Variables	160.8 m·min⁻¹ (N = 12)			Self-paced (N = 12)		
	NoJS	JS1	JS2	NoJS	JS1	JS2
VO_2 (ml·kg^{-1}·min^{-1})	40.0 ± 0.9	**42.6 ± 1.1**[c]	**42.7 ± 1.4**[b]	43.6 ± 1.9	**46.3 ± 1.5**[c]	**47.7 ± 1.6**[a, b]
energy expenditure (Kcal·min^{-1})	14.1 ± 2.0	**14.9 ± 2.1**[c]	**15.0 ± 1.8**[b]	15.2 ± 2.7	**16.2 ± 2.5**[c]	**16.8 ± 2.9**[a, b]
respiratory exchange ratio	0.85 ± 0.5	0.86 ± 0.7	**0.89 ± 0.4**[b]	0.89 ± 0.8	0.90 ± 0.5	**0.93 ± 0.6**[b]
% VO_{2peak}	77.2 ± 12.2	**81.9 ± 12.6**[c]	**82.6 ± 13.5**[b]	82.6 ± 8.6	**88.2 ± 9.3**[c]	**91.0 ± 8.6**[b]
V_E (L·min^{-1})	65.2 ± 15.1	69.7 ± 13.4	71.8 ± 13.3	72.1 ± 14.3	77.3 ± 15.5	**82.3 ± 14.6**[a,b]
HR (beats·min^{-1})	160 ± 4	164 ± 4	164 ± 5	168 ± 3	170 ± 4	172 ± 3
RPE	3.9 ± 0.5	4.8 ± 0.6	**5.5 ± 0.7**[a,b]	5.1 ± 0.4	**6.0 ± 0.4**[c]	**7.0 ± 0.4**[b]

a) JS2 significantly higher than JS1 ($P<0.05$)
b) JS2 significantly higher than NoJS ($P<0.05$)
c) JS1 significantly higher than NoJS ($P<0.05$)

Part 2 – Outdoor greenway

For the 160.8 m·min^{-1} trial on the greenway, VO_2, energy expenditure (Kcal·min^{-1}), and %VO_{2peak} were significantly higher during JS1 and JS2, compared to NoJS ($P<0.05$). However, there were no significant differences between JS1 and JS2 for any of these variables. RER was significantly higher during JS2 compared to NoJS ($P<0.05$). There was no significant difference in HR when comparing running with the jogging stroller to running without. RPE was significantly higher for JS2 compared to NoJS and JS1 ($P>0.05$).

For the self-paced trials, significant differences in VO_2, energy expenditure (Kcal·min^{-1}), and %VO_{2peak} were detected ($P<0.05$) across conditions (**Table 4**). Unlike the 160.8 m·min^{-1} trial, there were significant differences in VO_2, energy expenditure (Kcal·min^{-1}), and %VO_{2peak} between pushing 11.36 kg (JS1) and 22.72 kg (JS2) in the jogging stroller. There were no significant differences in HR found when running at a self-selected pace with and without the jogging stroller. RER was significantly higher for JS2 compared to NoJS and JS1 ($P>0.05$). V_E was significantly higher during JS2 compared to NoJS ($P<0.05$). However, RPE was significantly higher when running with the jogging stroller ($P<0.05$).

Discussion

The purpose of this study was to determine the extent to which physiological variables were affected by running with a jogging stroller on a track and on a paved, urban greenway. In Part 1 of the study, HR, V_E, and RPE were the only variables that differed among trials and only for the 160.8 m·min^{-1} trial. In Part 2 of the study, the data indicated that there was a significant increase in VO_2, energy expenditure (Kcal·min^{-1}), RER, %VO_{2peak}, V_E, and RPE when running with a jogging stroller compared to running without a stroller. It was expected that these variables would all show significance since they are all interrelated. HR was higher when running with the jogging stroller, but the difference was not statistically significant. The higher VO_2 and RPE seen when pushing the jogging stroller may be a result of altered stride frequency, rolling resistance, and increased external load that occurred when pushing the stroller over hilly terrain.

In Part 1 of the study, the only significant difference occurred for HR, V_E, and RPE during the 160.8 m·min^{-1} trial. On the track, HR was significantly higher during the 160.8 m·min^{-1} pace, although this may not be clinically significant since HR increased by only 6 beats·min^{-1}compared to the 4 beats·min^{-1} increase on the greenway. V_E was increased without a simultaneous increase in metabolic variables. The increase in V_E was due to greater breathing frequency and tidal volume. Each of these factors contributed equally to the increased ventilatory response. Blood lactate levels and stride frequency have the potential to impact V_E; however, these factors were not assessed in this study. Therefore, it is difficult to determine the cause of the altered ventilatory response during this trial. There are a variety of factors that could account for the lack of statistical significance in the metabolic variables. One factor may be the low rolling resistance of the jogging stroller on the smooth track surface. This probably decreased the amount of work necessary to push the jogging stroller, resulting in very little change in VO_2. An additional factor may be that this particular stroller has large wheels and shock absorbers intended to ease maneuverability while running, that further reduce the effort needed to push the jogging stroller.

In Part 2 of the study, the difference in VO_2 may be a result of stride frequency changes associated with pushing the jogging stroller or the additional work of pushing the combined weight of the jogging stroller and the 11.36 kg and 22.72 kg weights on hills. However, the jogging stroller is designed to reduce the amount of rolling resistance. This in turn may reduce the physiologic and metabolic response to running with a jogging stroller. Unfortunately, this investigation did not measure stride frequency or rolling resistance. The weight of the stroller (9.68 kg) and the simulated child weight amounted to 21.04 kg and 32.4 kg, consisted of approximately 30 % and 46 % of the mean body mass of the adult participants. This is a relatively large additional mass that only increased VO_2 by 2.7 ml·kg^{-1}·min^{-1} (160.8 m·min^{-1} pace) and 4.1 ml·kg^{-1}·min^{-1} (self-paced) when pushing the jogging stroller. This suggests that the energy cost of pushing a jogging stroller is similar to that of carrying a 1.81 kg handheld weight while running at 8 km/h, which increased VO_2 by 2.7 ml·kg^{-1}·min^{-1}[6]. Graves et. al. [8] found walking at 6.3 km·h^{-1} and 6.3 % grade with a 1.36 kg handheld weight increased VO_2 by 3.8 ml·kg^{-1}·min^{-1}. Therefore, running with a jogging stroller induced only a small amount of additional physiological stress on the participants.

Part 2 of the current study did not result in a significantly higher HR when running on the greenway. During the 160.8 m·min^{-1} trials for both parts of the study, RPE was significantly different only when comparing NoJS and JS2. The self-paced trials resulted in a greater difference across all conditions. This is comparable to the observations of Garcin et. al. [7] when participants walked on the treadmill at 3.7 km·h^{-1} and 4.7 km·h^{-1} while pushing an external load that ranged from 6 to 10 kg. RPE increased with each additional mass; however, RPE increased to a greater extent when walking at the faster speed.

Brown et al. [4] observed similar differences in VO_2 compared to part 2 of the current investigation, when running with a stroller ($4\,ml \cdot kg^{-1} \cdot min^{-1}$ vs. $2.7–4.1\,ml \cdot kg^{-1} \cdot min^{-1}$, respectively). This may be due to both studies using similar running surfaces, with Brown et. al. [4] using a concrete sidewalk and the current study using a paved greenway. Significant differences in HR were found by both Brown et. al. [4] and Smith et. al.[16], a finding that was not observed in the current study. This is somewhat surprising considering the well-established relationship between VO_2 and HR [1]. This finding may be due to the participants being acclimated to running with the jogging stroller. Similar RPE differences were found in the present study and that of Smith et al. [16] , but Brown et. al. [4] observed no significant change in RPE. This is attributable to the participants being instructed to run at the same perceived exertion during all performance testing in the Brown et al. [4] study.

A strength of the current study was that the participants were recreational runners accustomed to using jogging strollers, as opposed to individuals who had no prior experience using a jogging stroller [4, 16]. Also, the current investigation used both a track and a free-living natural environment (greenway). This allowed for elevation changes and the maneuvering of turns and obstacles, which may be typically encountered by runners using jogging strollers. A limitation of the study may be the higher fitness level of the participants. This may have made the runners more economical and perhaps reduced the energy cost of running with the jogging stroller. Another limitation of the current investigation is that we did not measure the stride frequency of the participants, the rolling resistance, or the forces applied to the jogging stroller.

Physically active parents have an excellent opportunity to maintain a healthy lifestyle while using a jogging stroller. Not only are they able to meet their personal physical activity and fitness goals, but they are also addressing their childcare needs and exposing their children to a healthy, active lifestyle at the same time. Using a jogging stroller reduces the barriers to physical activity faced by parents of young children. The current study shows that using a jogging stroller on an outdoor greenway increases $VO_{2,}$ by approximately 1 MET and an additional 12 kcal per mile, without causing over exertion or undue stress to the participants.

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