



Cardiovascular Drift while Rowing on an ErgometerMicah L. Hartwell¹, Jennifer L. Volberding¹, David K. Brennan²¹Oklahoma State University, Stillwater, Oklahoma, ²University of Oklahoma Center for Exercise and Sports Medicine, Human Performance Laboratory, School of Community Medicine, Tulsa, Oklahoma

ABSTRACT

Hartwell MH, Volberding JL, Brennan DK. Cardiovascular Drift while Rowing on an Ergometer. **JEPonline** 2015;18(2):95-102. Cardiovascular drift (CV_{drift}) refers to the gradual increase in heart rate (HR) during steady-state exercise. It has been shown to occur after ~15 min into running and cycling. Heart rate variability and CV_{drift} have yet to be analyzed during rowing on an ergometer. Two groups of 10 male collegiate rowers performed a 60-min session on an ergometer wearing HR monitors with HR measured at 1-min intervals. Demographic variables, post-workout dehydration, and ambient room temperature were measured. Descriptive statistics, dependent and independent samples *t*-tests, Pearson's correlation coefficients, and linear regression were conducted to analyze variables. Stabilization of HR following the acclimation phase of exercise differed in rowing versus the role of cycling and running on the CV_{drift}. These findings may alter the current approach to adapting cycling and running HR training regimens to the sport of rowing and may even necessitate that rowing coaches develop their own training regimens when using HR as a monitoring mechanism. The results suggest that target HR training zones may be unique for the sport of rowing.

Key Words: Rowing, Cardiovascular Drift, Heart Rate

INTRODUCTION

Many elements of rowers' physiology have been recorded and are regularly used in the application of rower training regimens. However, cardiovascular drift (CV_{drift}) has not been evaluated among the elements. Cardiovascular drift is the phenomenon in which, during steady-state exercise (i.e., running, cycling) at moderate intensity, a gradual increase in heart rate (HR) occurs despite no overall change in workload (7). When coupled with a decline in stroke volume (SV), an increase in HR will allow for a constant cardiac output (Q).

Heart rate variability in runners and cyclists is known to follow a certain pattern during exercise that includes: (a) acclimation; (b) stabilization; and (c) CV_{drift} . Acclimation occurs at the onset of exercise with an increase in HR to accommodate the increase in metabolic demand for oxygen. The stabilization phase occurs when the body reaches a homeostatic level that balances HR and Q with oxygen and energy for muscle contraction. Research on runners and cyclists indicate that an upward climb in HR occurs, which is known as the CV_{drift} , after roughly 15 min of exercise. Then, it continues to gradually increase beyond 2 hrs (4).

Knowing when and why CV_{drift} occurs among athletes of different sports is an important factor in improving performance and attenuating the causal factors to improve endurance. For example, Coyle and Gonzalez-Alonso (4) observed CV_{drift} in cyclists over a 120-min session in control conditions. The subjects' increase in HR was strongly correlated with the increase in core body temperature ($r = 0.95$) and dehydration status (4). The relationship between HR elevation and dehydration was reported to be related to the decrease in blood plasma, which resulted in the decrease in SV (given that 3 to 5% dehydration of body weight reduces blood volume by the same percentage).

Interestingly, no research exists regarding CV_{drift} in rowing, yet some previously studied factors may influence if and when CV_{drift} occurs including heart size, muscle recruitment and involvement, overall power output compared to other sports and posture (i.e., the effect of a seated position as opposed to the more erect stance of cycling and running). A comparison of HR between rowing and running showed lower HR responses in rowing with a higher power output (2). The lower HR may indicate that during rowing more control is required throughout the cardiopulmonary system. Maximal oxygen uptake was significantly higher during rowing, which suggests that the athlete's body position, the involvement of muscles used during rowing or a combination of both allows for a lower HR for the same exercise intensity.

Despite the higher demand for oxygen circulation during rowing due to the power strain on muscles, the seated position allows for the elevated flow of blood to and from the limbs to be directed through horizontal, not vertical, transport (21). Additionally, at the beginning of each stroke an athlete performs a Valsalva maneuver that increases pressure within the central body that allows for increased pressure and force through the trunk. However, the pause in breathing during rowing produces a significant increase in blood pressure (17) while seated that accommodates the increase (19). This technique generates more torque, but places a heavy load on the heart and is related to the ventricular hypertrophy of rowers compared to other sports (12). Overall, the combination of position and rowing technique allows for a higher VO_2 max and a maximized work load (20).

Given that studies have shown rowing and cycling have similar oxygen requirements in transition from moderate to heavy workloads, it would seem that a similar interaction of HR would follow (15). However, cycling cadence has been shown to cause large variations in the onset of CV_{drift} between pedal revolution frequencies of 40 to 80 $\text{rev}\cdot\text{min}^{-1}$, where the higher $\text{rev}\cdot\text{min}^{-1}$ created a significant difference in the culmination of CV_{drift} (9). The slower, more powerful stroke rate in rowing may produce a different pattern of CV_{drift} . This may be why training regimens for competitive rowers usually require 70% or more sport specific exercise (11); whereas, other sports may benefit from a greater proportion of cross-training.

Given that HR training zones have been generalized for other sports, this research should provide a base of knowledge and understanding of CV_{drift} specific to rowing. Due to unique physiological demands of rowing, this observational study had three objectives: (a) to measure the HR variability of the collegiate athletes during a 60-min ergometer session; (b) to determine whether CV_{drift} follows a similar pattern observed in other sports during a 60-min ergometer session; and (c) to identify variables related to increases in HR over time.

METHODS

Subjects

Twenty collegiate male rowers from a small Midwestern university volunteered to participate in this study. The purpose for choosing experienced rowers is that the difference in technique and skill varies significantly between novice and veteran rowers (14), with experienced rowers having a high reliability of performance (16). Inclusion criteria for the study consisted of male subjects aged 18 yrs or older, active membership in the college's rowing team, and completion of the Physical Activity Readiness Questionnaire (PAR-Q). Approval for the study was granted by the Institutional Review Boards at Oklahoma State University and Oklahoma City University. Prior to the data collection, written informed consent was obtained and a Physical Activity Readiness Questionnaire (PAR-Q) was completed (18).

Procedure

Prior to the study, the subjects underwent a 2000 m test to provide the researchers with maximal exertion scores for each rower. The scores were used to calculate target wattage output for the 60-min bout. The projected output for each subject was determined at his 65% HR reserve (HRR), or the difference between the maximum HR and resting HR. Under the assumption that the subjects' resting HR was under 99 $\text{beats}\cdot\text{min}^{-1}$, this study used the following formula to calculate the training zones: $\text{Target HR} = (\text{HRR} \times 65\%) + \text{RHR}$.

The data were collected on the same day during two sessions that comprised 10 subjects each. The first session was at 3:00 p.m. and the second was at 6:30 p.m. in accordance with the team's practice schedule. Changes in hydration status were documented with pre- and post-weighing in appropriate rowing attire. The degree of dehydration was examined in percent of body weight lost. Ambient room temperature was recorded during each session. The subjects were fitted with Polar Wearlink®+ Transmitter with Bluetooth® (Polar, NY) (13) HR monitor chest straps. Resting HR was recorded before the start of the session. Then, the subjects were instructed to maintain a given wattage output throughout a 60-min rowing session on an ergometer (Concept2, VT) (3). Heart rate was recorded

each minute for each subject. After the conclusion of the exercise session, the subjects rested for 3-min. Then, their final HR and post-exercise weight were recorded.

Statistical Analyses

The data were analyzed using SPSS Statistics (IBM, NY) (8). The demographic data, physiological measures, and psychological measures were reviewed using descriptive statistics. Between-group differences were analyzed using an independent-samples *t*-test. Using the Pearson's correlation coefficient, bivariate correlations were used to identify significant associations between variables of interest. Scatterplots and interpolation lines were constructed to examine mean HR overtime.

RESULTS

The subjects' had a mean age of 20.10 (SD = 1.17) with experience ranging from 3 to 9 yrs of rowing in a team setting (M = 5.60, SD = 1.93), with 20% of the subjects competing on either the junior or U23 (under 23) national teams. Anthropometric measurements are presented in Table 1.

Table 1. Comparison of Characteristics of the Two Groups.

	Combined Groups (n = 20)	Group 1 (n = 10)	Group 2 (n = 10)	Significance ($\alpha = 0.05$)
Age (yrs)	20.10 $\pm$ 1.17	19.90 $\pm$ 1.10	20.30 $\pm$ 1.25	$t(18) = .759$ P = .458
College Schooling (yrs)	2.40 $\pm$ 1.14	2.40 $\pm$ 1.17	2.40 $\pm$ 1.17	$t(18) = .000$ P = 1.00
Experience Rowing (yrs)	5.60 $\pm$ 1.92	5.55 $\pm$ 2.03	5.65 $\pm$ 1.92	$t(18) = .113$ P = .911
Aerobic Exercise (min)	31.00 $\pm$ 35.82	14.00* $\pm$ 20.66	48.00* $\pm$ 40.50	$t(18) = 2.365$, P = .029
Strength Training (min)	15.75 $\pm$ 30.58	22.5 $\pm$ 40.77	9.00 $\pm$ 14.49	$t(11.238) = .987$ P = .345
Body Mass Index (kg·m⁻²)	25.10 $\pm$ 2.88	25.08 $\pm$ 3.52	25.12 $\pm$ 2.26	$t(18) = .03$ P = .976
Height (in)	73.39 $\pm$ 3.01	72.48 $\pm$ 3.19	74.3 $\pm$ 2.67	$t(18) = 1.389$ P = .182
Baseline Weight (lbs)	192.32 $\pm$ 24.5	187.18 $\pm$ 27.25	197.46 $\pm$ 21.59	$t(18) = .935$ P = .362
Weight Loss (%) Baseline wt – post-test wt ÷ baseline wt	1.39 $\pm$ 0.48	1.47 $\pm$ 0.27	1.30 $\pm$ 0.63	$t(18) = .783$ P = .444

Independent *t*-tests between Group 1 and Group 2. *Statistically significant difference between groups (P<0.05)

Paired samples *t*-test found a significant difference ($P < 0.001$) between pre-weight ($M = 192.32$, $SD = 24.50$) and post-weight ($M = 189.65$, $SD = 24.14$), which indicated dehydration. There were no significant differences between the groups with the exception of minutes of aerobic exercise training per week outside of team practice, with Group 2 having a higher average compared to Group 1. Additionally, the ambient room temperature differed between the groups (67°F Group 1 and 61°F Group 2). Descriptive statistics were also reviewed to compare physiological measures across and between groups. Independent samples *t*-tests were conducted. However, there were no observed differences between the groups for average HR, starting HR, peak HR, and percent HR change from 3 min to 60 min.

No significant correlations were found for room temperature, average HR, 60-min HR, and dehydration. The subjects' 60-min HR was significantly associated with additional minutes of aerobic exercise per week ($r = -.529$, $P < 0.05$) as well as the number of years of rowing ($r = -.471$, $P < 0.05$). As additional minutes of weekly exercise and the number of years' of experienced rowing increased, the 60-min HR decreased. The CV_{drift} occurred during each of the trials after the initial acclimation phase, which was in response to the physical exertion across minutes and the necessary energy expenditure. Figure 1 shows the mean HR for the athletes from combined groups over time. No settling phase was observed between the first 5 min to 20 min of the session. Instead, the subjects' HR increased at a steady increment following the acclimation phase.

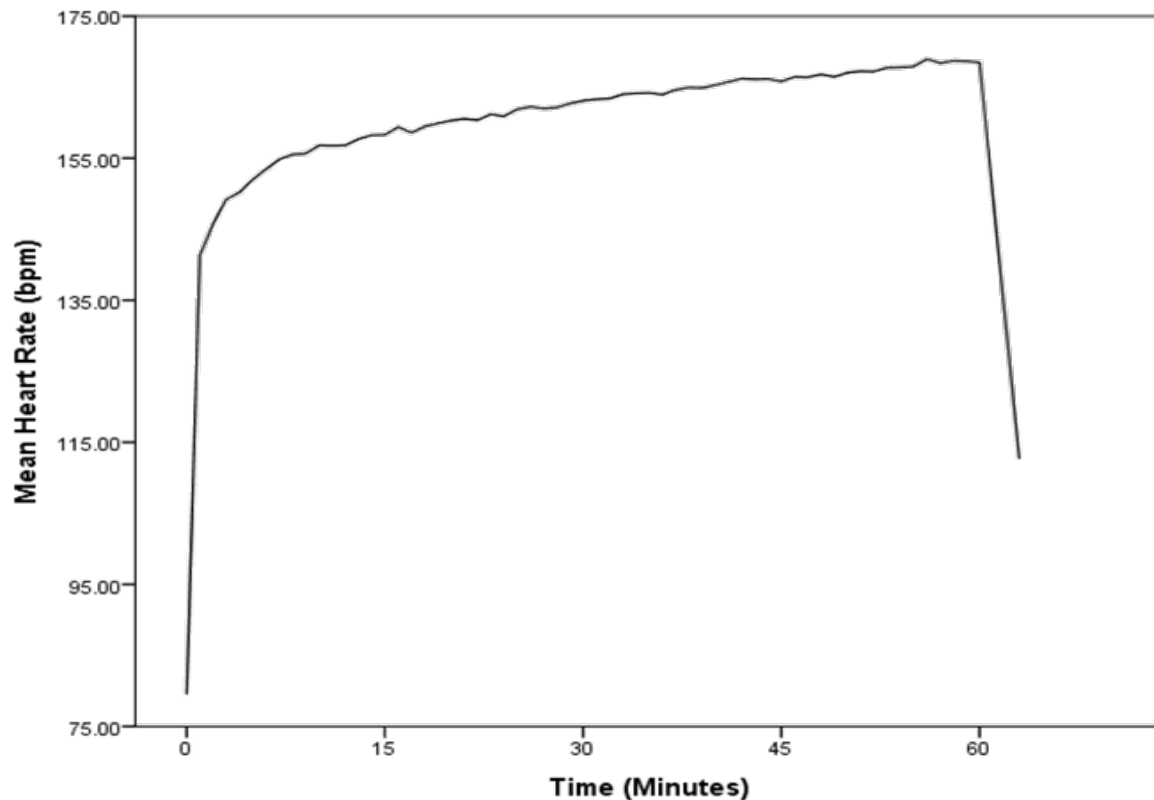


Figure 1. Heart Rate Progression during 60 Min of Rowing on an Ergometer at 65% Projected HRR. Observation of HR during Steady-State Rowing on an Ergometer shows Cardiovascular Drift occurring after ~3 Min.

A paired-samples *t*-test was calculated to compare the mean HR at 3 min ($M = 149.16 \text{ beats} \cdot \text{min}^{-1}$, $SD = 6.67$) to the mean HR at 60 min ($M = 168.37 \text{ beats} \cdot \text{min}^{-1}$, $SD = 8.43$). A significant increase in mean HR was found, $t = 14.10$, $P < 0.001$. To eliminate the possibility of an increase in exertion (watts) as an explanation for the significant increase in HR, a paired-samples *t*-test between exertion (watts) at 3 min ($M = 199.95 \text{ watts}$, $SD = 25.63$) and 60 min ($M = 199.40 \text{ watts}$, $SD = 23.77$) found no significant change in wattage from 3 min to 60 min, $t = 0.566$, $P = .578$.

DISCUSSION

The results of the present study indicate that the CV_{drift} occurred during a prolonged session of rowing without a noticeable stabilization phase (refer to Figure 1). There is a continual gradual shift upwards in HR over the duration of exercise exhibiting the attributes of a CV_{drift} . Studies of HR variability during running and cycling indicate a significant stabilization period occurring from 5 min to 15 min from the start time before a drift in HR occurs. The implication is that under steady-state rowing conditions, the onset of CV_{drift} may not be as delayed as in other sports. The lack of a stabilization period of HR during rowing may be caused by sport-specific physiological mechanisms, the physical attributes of rowers, and the ergonomic position of the body during rowing. While understanding the rowers' HR response may lead to better training routines for rowing, it may also provide a benefit to cross-training other athletes and professionals as well as military personnel.

This study showed no settling phase with the slowing in HR progression at the 3-min mark. Instead, HR continued to progress upwards at a steady rate through the 56-min mark. Factors that may be involved in the subjects' HR response are: (a) the lower cadence of the repetitive motion of rowing versus that of running and cycling; (b) the motion of rowing involves all the major muscle group working in synch, forcing the transition through the energy cycles more quickly than in running or cycling; (c) the increased size of the rowers' left ventricle, which may be better equipped to maintain a steady workload, increasing the HR earlier but with a lower consistent slope; and (d) the larger VO_2 max that is generally attributed to rowers (20).

The onset of CV_{drift} in this study occurred earlier than that observed in other sports. For example, the stabilization period during cycling is reached after approximately 10 min and continues until 20 min have passed. At this time, HR accelerates much more quickly through the end of the session (5). Mean HR in rowers did not accelerate quickly, but rather a gradual rise in HR began earlier and continued at a steady upward rate, accounting for an average increase of 120.04% from 3 min to 60 min ($SD = 39.08\%$).

Several variables may affect the CV_{drift} observed in rowers. One contributing factor to CV_{drift} in this study may be the hydration status of the rowers as increased dehydration increases HR and can exacerbate CV_{drift} (6). The participants of the study had a mean weight loss of 2.67 lbs, an average of 1.39% of bodyweight ($SD = 0.48\%$). Dehydration, as previously discussed, can have a significant impact on cardiac drift in which the percentage of body weight lost results in a decrease in the same percentage of blood volume as suggested by the data. Exercise took place at temperatures of 67°F and 61°F for Groups 1 and 2, respectively, which were below the recommended guidelines (1). There was no significant influence of temperature on CV_{drift} between groups.

Limitations

Limitations of the present study included: (a) the location and timing that were coordinated by the team's training regimen; (b) the fact that the subjects' food intake and/or the use of ergogenic aids were not controlled; and (c) lastly, there were no psychological testing of the subjects' mood or attitude toward the testing protocol.

CONCLUSIONS

The phenomenon of CV_{drift} in rowing was demonstrated on an ergometer. The increase in HR after the first 3 min was almost linear with a lack of settling phase as seen in cycling. The similarity of the increase in HR between the two groups observed indicates the test could be replicated and the results are applicable to further research within the sport of rowing.

This study's findings are important in application because it may change the way rowing coaches implement similar training methods to cycling and running. Because of the lack of settling phase during the first 15 min of rowing, monitoring HR during this exercise may need more research to determine optimal training zones. Training methods and optimal zones may need to be altered and re-evaluated throughout the rowing season when athletes change from rowing long distances in the fall to shorter sprints in the spring and summer.

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