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Heart Rate Responses and Fluid Balance of Competitive Cross-Country Hang Gliding Pilots

Darren P. Morton

Purpose: To evaluate the physiological challenges of competitive cross-country hang gliding. ***Methods:*** Seventeen experienced male pilots (age = 41 ± 9 y; mean ± SD) were fitted with a monitor that recorded heart rate and altitude at 0.5 Hz throughout a competitive flight. Fluid losses were evaluated by comparing pilot pre- and postflight mass. ***Results:*** The pilots' displacement was 88.4 ± 43.7 km in 145.5 ± 49.4 min. Mean flight altitude was 1902 ± 427 m (range = 1363–2601 m) with a maximum altitude of 2925 ± 682 m (1870–3831 m). The mean in-flight heart rate of the pilots was 112 ± 11 bpm (64 ± 6% predicted HRmax). For all except one subject, heart rate was highest while launching (165 ± 12 bpm, 93 ± 7% predicted HRmax), followed by landing (154 ± 13 bpm, 87 ± 7% predicted HRmax). No statistically significant relationship was observed between heart rate during the launch and reported measures of state anxiety. Heart rate was inversely related ($P < .01$) to altitude for all pilots except one. Fluid loss during the flight was 1.32 ± 0.70 L, which approximated 0.55 L/h, while mean in-flight fluid consumption was 0.39 ± 0.44 L. Six pilots consumed no fluid during the flight. ***Conclusions:*** Even among experienced pilots, high heart rates are more a function of state anxiety than physical work demand. Fluid losses during flight are surprisingly moderate but pilots may still benefit from attending to fluid balance.

Keywords: altitude, temperature, heart rate, fluid balance, anxiety, hang gliding

Competitive cross-country hang gliding pilots are confronted with extreme physical, emotional, and environmental stresses. Despite the unique challenges presented to competitors, the physiological demands of the sport have not been documented.

A competitive event involves the athletes racing around a course, referred to as a task, which is prescribed by a briefing committee in accordance with the weather conditions of the day. The task is typically 80 to 150 km in displacement, but can be in excess of 200 km, and is usually interspersed with several turn points. The pilot who completes the task in the fastest time, and can demonstrate with a global positioning system track log that all turn points were achieved, wins the event.

The event commences with the competitors launching from an elevated site (usually over 300 m above ground level) or being towed and released at a similar

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altitude by ground vehicle or microlight aircraft. While the process of launching is typically not of high physical work demand, anecdotally it can be associated with high levels of state anxiety. After successfully launching, the pilots attempt to gain altitude by locating and circling in "thermals," which are vertically aligned air currents released from disproportionately heated portions of the earth. Thermals are typically turbulent and negotiating them can be physically demanding, requiring substantial effort on behalf of the pilot to maneuver the weight-shift controlled glider from which they are suspended. The turbulence associated with thermals can also evoke anxiety.

The pilots can ascend in the thermal until it cools with the increasing altitude to dew point, which relates to the base of cumulus cloud. Cloud base is commonly over 3,000 m but the athletes do not carry supplementary oxygen. The rate of ascent achieved in thermals varies according to the conditions of the day but climb rates of over 300 m/min are common. On achieving satisfactory height in a thermal the pilot then glides to the next anticipated source of lift, often obtaining speeds in excess of 100 km/h. Descent rates on glide are greater than the maximal ascent rate for the day. The pilot then proceeds to repetitively ascend in thermal currents and glide to the next anticipated source of lift in an attempt to complete the entire task. Total flight time can be in excess of 5 h. The event concludes when the pilot lands the glider and this can be technically difficult to execute depending upon the ambient conditions and landing area.

As the pilots are openly exposed to the environment, they encounter barometric and associated thermal stress. Moreover, the ambient conditions vary rapidly according to the pilot's constantly changing altitude. The competitions are conducted during the summer months, due to the thermic intensity being greatest during this period, and hence ground temperatures can reach over 40°C while cloud base can be close to freezing. Wind chill greatly increases the thermal stress when gliding at high velocity.

The first aim of the current study was to record in-flight heart rate responses of hang glider pilots to determine the cardiovascular stresses of the sport. Heart rate has been measured in pilots of civil and military aircraft and these studies indicate that heart rate is not significantly elevated during level flight but does increase during take-off and landing.[1] Accordingly, it has been suggested that heart rate elevations are a function of increased arousal associated with cognitive stress.[1] Indeed, the relationship between cognitive stress and heart rate is well established[2] and demonstrated in activities such as parachuting[3] and motor car racing.[4] While it might be anticipated that the heart rate responses of hang glider pilots would be comparable to those of more conventional aircraft pilots, hang gliding differs in two distinct ways. Firstly, hang glider pilots are exposed to the ambient conditions. Secondly, being a weight-shift controlled craft, hang glider pilots are required to input greater levels of physical effort to navigate the craft and so the physical work demand would be expected to be higher. Recording the in-flight heart rates of hang gliding pilots may undergird the development of guidelines for improving performance and safety.

The second aim of the study was to document fluid losses incurred by the pilots while completing a task. Anecdotally, pilots do not adequately address the issue of hydration, possibly in an attempt to avoid having to urinate in flight. During his world-distance-record flight of 499 km in 2005, the Australian Jonny Durand Jr consumed no fluid during the 10-h flight (Durand, 2007, personal communication). Understanding the magnitude of fluid losses during an event would provide a better understanding of the hydration stresses associated with the sport and accordingly allow the development of fluid consumption guidelines for the pilots.

Methods

The study was conducted at the New South Wales State titles hang gliding competition, with the launch site being Mt. Borah, Manilla, Australia. Before participating in the study the pilots completed a medical clearance and provided informed written consent. Ethical clearance was obtained from the Avondale College Human Research Ethics Committee and the study was conducted in compliance with this body.

Participants

A convenient sample of 17 pilots (age = 41 ± 9 y, body mass index = 25.9 ± 2.8 $kg \cdot m^{-2}$; mean ± SD) were recruited for the study. The pilots were experienced in the sport of hang gliding, having logged 1766 ± 1407 h. Note that an "advanced" rating can be achieved from the Hang Gliding Federation of Australia after logging 80 h,[5] highlighting the level of experience of the subjects involved in this study.

Procedures

Approximately 1 h before launching the subjects were fitted with a heart rate monitor that also measured altitude (Suunto T6, Suunto Oy, Finland). The monitor was calibrated for the launch elevation of 878 m above mean sea level. The heart rate monitor was programmed to record heart rate and altitude at 0.5 Hz. Approximately 15 min before launching, before securing themselves in their harness, the pilots were weighed (A&D Instruments, model UC-321, England) and the volume of fluid contained in their drinking vessel for the flight, if they carried one, was quantified. The scales measured mass in 5-g increments. It is a limitation of the study that nude weight was not recorded but the logistics involved in taking this measure were deemed too disruptive to the pilot's preparation for the flight and may have compromised their safety.

Radio contact was maintained with the pilots after launching (ICOM, model IC-41S, Japan) and they were tracked throughout the flight and intercepted on landing. As soon as practical, before consuming any fluid or voiding, the pilots were weighed again. The volume of fluid remaining in their drinking vessel was also quantified. Fluid losses were calculated as the difference between the subjects' before and after body mass and fluid consumption was determined by assessing the change in the mass of their drinking vessel.

A questionnaire was administered following the flight to assess the pilots' perception of the launch and landing conditions, the level of turbulence encountered and any other noteworthy disturbances. The pilots were also asked to rate their level of perceived exertion for the flight on the Borg 15-point rating of perceived exertion scale.[6] Measures of state anxiety during launch and landing were derived from a modified version of the Competitive State Anxiety Inventory-2.[7] The questionnaire also asked questions relating to hydration such as the type of fluid consumed, whether fluid intake was limited to avoid having to urinate in flight, and if the pilot did urinate while in flight.

The heart rate and altitude data for the flight was later downloaded from the heart rate monitor for analysis using Suunto Training Manager version 1.3.3 (Suunto Oy, Finland). The data were imported into SPSS 15 for Windows (SPSS Inc) for analysis. For the purpose of comparing the subjects' mean and peak heart rates achieved during the flight, the pilots' maximum heart rate was predicted using the age-based method HRmax = 210 to 0.662 × Age.[8] The inaccuracies associated with predicting maximum heart rate are acknowledged, as presented by Robergs and Landwehr,[9] but the measure was deemed useful to contrast the mean and peak heart rates achieved by the pilots. No pilot was taking any medication that could have affected their heart rate or fluid balance.

Statistical Analysis

Data analysis was performed using SPSS 15 for Windows (SPSS Inc). Descriptive statistics involved percentages and mean ± standard deviation. Pearson's correlation analysis was used to examine relationships between heart rate and both altitude and the measures of the pilots' state anxiety during launch and landing. A paired *t* test was used to determine differences between the pilots' heart rate at the peak of their flight and at the lowest point not associated with landing. The .05 level of significance was adopted.

Results

Flight Details

The pilots launched between 12:30 and 4:30 PM during which time the ground temperature varied between 32.9 and 38.5°C (35.6 ± 2.0°C) with a mean barometric pressure of 1006.8 ± 4.1 hPa. Sixty-nine percent of the pilots reported that the launch conditions were ideal and none responded that the conditions were dangerous. Only 19% of the pilots indicated that they felt scared or apprehensive about launching. Similarly, only 13% reported feeling apprehensive or scared at the conclusion of the flight when landing.

The mean flight time was 145.5 ± 49.4 min. The pilots' mean displacement was 88.4 ± 43.7 km with a mean flight altitude of 1902 ± 427 m (range = 1363–2601 m) and maximum altitude of 2925 ± 682 m (1870–3831 m). The level of turbulence encountered during the flight, as rated by the pilots, was none (50%), light (44%), and moderate (6%). When questioned regarding noteworthy disturbances during the flight, 18% of the pilots reported having come in close proximity to other gliders and 12% claimed to encounter cloud, both of which can present safety hazards. The mean rating of perceived exertion for the flight was 12.1 ± 1.3, which fell between "light" and "somewhat hard."

Heart Rate Responses

For all except one subject, heart rate was highest when launching (165 ± 12 bpm, 93 ± 7% predicted HRmax), followed by landing (154 ± 13 bpm, 87 ± 7% predicted HRmax). Interestingly, no statistically significant relationship was observed between heart rate during the launch and reported measures of state anxiety at the time ($r = -0.33$, $P = .22$). Similarly, there was no statistically significant correlation between the pilots' heart rate when landing and reported measure of state anxiety ($r = -0.08$, $P = .77$).

The pilots' mean heart rate during the flight was 112 ± 11 bpm (64 ± 6% predicted HRmax). Heart rate was inversely related ($P < .01$) to altitude for all except one pilot. This trend remained for 14 of the pilots when the high heart rates surrounding the launch and landing phase were omitted by removing the initial and final 5 min of each pilot's flight data. The pilots' heart rate at their maximum altitude (107 ± 14 bpm) was significantly lower ($P = .004$) than their heart rate at the lowest point of their flight not associated with landing (114 ± 12 bpm).

Fluid Losses

Mean fluid loss during the flight was 1.32 ± 0.70 L (0.30–3.00 L), which approximated a rate of 0.55 L/h. Mean fluid consumption during the flight was 0.39 ± 0.44 L resulting in a net loss of 0.96 ± 0.78 L, or approximately 0.40 L/h. Six pilots consumed no fluid during the flight. Of the 11 pilots who did consume fluid during the event, one consumed a sports drink with the rest water. Only 3 of the 17 pilots claimed to limit how much fluid they consumed to avoid having to urinate during the event and only one pilot reported having to urinate while in flight.

Discussion

As the sport of competitive cross-country hang gliding has evolved, the demands on competitors have increased with pilots being required to fly further, higher, and at greater speeds to be competitive. This is the first study to document the physiological stresses of this sport, which is rather unique in regards to the challenges it presents to its participants. Few sports, if any, involve the potential for heat stress, cold stress, hypobaric stress, and high levels of anxiety, all within a single event.

Despite the stresses associated with the sport, the relatively low mean heart rate of the pilots once in flight suggests that it is not of high cardiovascular demand. This is further indicated by the low rating of perceived exertion scores reported by the subjects. These data imply that from the perspective of optimizing performance, a high level of cardiorespiratory fitness is not required to excel in the sport. However, while mean heart rate was only around 65% of predicted maximum, the sport does require considerable endurance, given that a competitive event can extend for over five hours. Certainly, many pilots appear exhausted at the completion of a task. Anecdotally there seems to be perception among many of the elite pilots that physical conditioning exercises other than "time in the air" have limited value, although a few members of the Australian team participate in endurance activities such as cycling and kayaking in the off-season to better their competitive hang gliding performance.

It would be interesting to replicate this study with less experienced pilots or in conditions that the pilots deemed turbulent as both of these may result in higher mean heart rates. The heart rates of less experienced pilots would likely be higher due not only to higher arousal levels but also to increased physical workload as they tend to be less efficient in controlling the craft. Similarly, greater turbulence would call for more pilot input, even among experienced pilots, which may in turn result in higher exertion scores and associated heart rates. It is somewhat surprising that the pilots involved in the study deemed the level of turbulence to be "low" as the conditions were very unstable, characterized by localized thunderstorms. The low ratings of turbulence may have been due to their extensive experience and familiarity with unstable conditions.

While the sport of hang gliding appears to be of low work demand there are brief periods of high intensity, especially when launching and landing. These data are consistent with commercial airline studies, although unlike the current study the heart rates of commercial pilots are typically higher when landing than taking off.[1] Clearly, the high heart rates observed at these times are attributable to anxiety as compared with physical exertion. In the current study the launch used was a cliff and therefore required only a few steps to initiate flight. In addition, the high heart rates observed when landing occurred in the preparation phase before the pilot had even touched the ground. The influence of anxiety on heart rate is evident in other sports such as parachuting, in which the highest heart rates are recorded at the time of the parachute opening.[3] In motor car racing, heart rates corresponding to 90% of maximum have been reported,[4] which is strikingly similar to the peak rates observed in the pilots of the current study.

As an indication of arousal level, the high heart rates observed during the launch and landing are informative from a safety perspective. Anecdotally, the vast majority of hang gliding incidents occur during the launch or landing phase. It is interesting that the pilots, highly experienced as they were, claimed not to be anxious when launching or landing but their heart rates told a different story. This poor relationship between reported anxiety level (cognitive state anxiety) and somatic state anxiety (heart rate) is consistent with studies of the anxiety response.[7] The fact that measures of cognitive anxiety and somatic anxiety are often poorly correlated has prompted theorists to view the two as independent, albeit covarying.[7,10] Also consistent with studies of the anxiety response is the observation that the pilots' somatic state anxiety (heart rate) peaked before the anxiety producing moment and then dissipated once it had been executed.[7] It is widely accepted that increasing arousal narrows perceptual field, with high levels of anxiety resulting in an individual missing important cues relevant to performance which impedes information processing and decision making ability.[11] In the sport of hang gliding, the pilot is required to process numerous cues, especially when launching and landing, and the consequences of not performing this effectively can be devastating. A question for further investigation asks whether a pilot who thinks they are not anxious, as in the case of the pilots in this study, but concurrently demonstrates a high level of somatic state anxiety, is compromised in their ability to process information and make safe decisions. What is clear is that the launch and landing phases of competitive hang gliding present the greatest safety concern and even highly experienced pilots appear to be subconsciously aware of this fact. Yet as launching and landing constitute a small portion of the overall event, relatively little time is spent in developing and maintaining these skills. To improve the safety of the sport, pilots of all levels would benefit from practicing launching and landing to ensure a high level of proficiency in these basic skills.

The observation that heart rates were lowest when the pilots were at their highest altitudes is interesting as the opposite might be expected due to the potential for anxiety associated with the considerable heights attained as well as the rarefied air encountered at these altitudes. At the peak altitudes achieved (2925 ± 682 m), with one pilot attaining 3831 m, the partial pressure of oxygen would be reduced by approximately 36%, resulting in hypoxia and increased cardiorespiratory demand. If the hypobaric conditions encountered at the peak of flight in the current study did increase heat rate, the effect was masked by more dominant factors. The most important of these factors is likely a decrease in arousal with increasing altitude. While this may be counterintuitive to those unaccustomed with the sport, altitude gain for the pilot means increased time for decision making, a decreased immediate danger of having to land, and a reduced risk of being terminated from the contest. Further, the level of turbulence typically decreases with increasing altitude as the air becomes more uniform. A final factor that could conceivably have reduced heart rate at altitude was the cold temperature. Pilots are especially exposed to the cold on their face and hands and while all the pilots wore gloves, 81% flew without a visor for face protection. As a result, their face would have been subject to wind chill when gliding at speed at the higher altitudes. Conceivably, the pilots may have experienced a derivation of the mammalian diving reflex, which can trigger bradycardia when the face is exposed to cold stress.[12]

The fluid losses experienced by the pilots in the study appear surprisingly moderate. However, when it is considered that the pilots spent little time in the hot and dry conditions that prevailed at ground level during the hours of the competition the fluid losses are understandable. Applying the standard environmental lapse rate of a 6.5°C decrease in temperature for every 1000 m gain in altitude,[13] the temperature at the pilots' mean elevation would have been approximately 22°C. Indeed, the fact that the pilots wear gloves and warm clothing testifies that they are most concerned with reducing heat loss during flight. The most significant fluid losses probably occur before launching as this is when the pilots are exposed to the high temperatures.

While the fluid losses on average were only slightly more than one percent of body mass, some pilots lost up to 3.00 L during the event, which amounted to over three percent of body mass. From a physical work capacity viewpoint, the impact of dehydration is probably not a major concern as the sport is not a high cardiorespiratory demand, but it might be of concern from a cognitive performance perspective. The limited studies on dehydration and cognitive performance suggest that at around two percent dehydration, attention is impaired and visual motor tracking ability is compromised.[14] Both these capacities are important in competitive hang gliding. Anecdotally, many hang gliding pilots complain of headaches following an extended flight but it is unclear whether this is due to dehydration or other factors such as the prone body position with neck hyperextension that is adopted during flight. Regardless, pilots could benefit from being more intentional with regards to the maintenance of fluid balance. For the subjects in this study, maintaining fluid balance would have involved consuming on average an additional 400 mL/h, although this quantity was highly variable. Pilots could most benefit from determining their individual fluid losses and developing a personal fluid consumption protocol.

Conclusions

The results of the study indicate that competitive cross-country hang gliding is not of high cardiorespiratory demand but still calls for a level of endurance. High heart rates appear more related to state anxiety than physical work demand. Launching and landing appear to elicit high levels of somatic state anxiety, even among elite performers, emphasizing the importance of a high technical proficiency in these skills. Fluid losses during flight appear surprisingly moderate but pilots may still benefit from attending to fluid balance.

Practical Implications

The sport of competitive cross-country hang gliding is not of a high physical work demand. Accordingly, without devaluing the merit of conventional fitness training, it may only provide limited benefits to the performance of competitive pilots. The best form of training is likely to be "time in the air." Even highly experienced hang gliding pilots demonstrate high levels of somatic anxiety when launching and landing, highlighting the importance of being proficient and current in these skills. While fluid losses during flight are on average surprisingly moderate, pilots may still benefit from developing a personal hydration protocol, especially from the perspective of cognitive performance.

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