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PERFORMANCE CHARACTERISTICS OF ADULT ONE DOG CANICROSS RUNNERS

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ABSTRACT

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Canicross is competitive team sport in which a human athlete is towed via a canine athlete on an elastic gangline. Although drastically understudied, it is likely that canicross performance comes down to differences in human aspects, canine aspects and the interaction between human and canine. The purpose of this study is to identify and assess the influences of several performance factors on a time trial canicross event. Survey data was taken upon arrival at the event. During the event, video was taken at five locations along the trail of two different competitive canicross events. Correlation analysis was used to identify relationships between all independent variables taken from survey and video data. Further, a multiple linear regression analysis was used to predict time-trial performance and a one-way repeated measures ANOVA was used to determine differences in synchronization scores across locations. The results of this study found significant correlations between performance and the time spent in training without the dog, as well as, normal dog position. Regression analysis revealed that performance can be predicted via percentage of time spent in overall canine front left foot flight and overall human mid-stance, in relation to overall stride. Lastly, synchronization scores did not differ significantly across locations. Future research should continue to investigate optimal synchronization patterns in high-level canicross athletes.

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INTRODUCTION

The utilization of sled dogs dates back to the early 1800's where teams of dogs were used to haul supplies to areas that were otherwise inaccessible due to snow and extreme weather conditions (1). Through the years the traditional purposes of sled dogs have evolved into competitive races ranging in distances from one to over 1,000 miles on snow and dry land (1, 2). Dryland racing, best described as a sled dog race without the snow, is run during the fall season where mushers utilize wheeled rigs or movement on foot in place of the traditional sled (2). Canicross is an aerobic sport run within dryland racing in which the musher or human athlete runs behind a one or two dog team, attached via a harness and an elastic gangline or rope (2). Unfortunately, both the human and canine aspects of this sport have been drastically understudied (3). One study investigated the amount of time spent training individually (human and dog separate) for a canicross event, but they did not identify or assess team performance (3). They found that the average human training sessions per week was 4.35 sessions whereas the average training sessions for the canines were 2.36 sessions (3). Overall, they concluded that although the human participant has more training sessions per week, they did not know how that affected team performance (3).

In human aerobic performance, a successful athlete is said to have three physiological characteristics that contributes to their performance; high VO_{2max}, the ability to sustain a high percentage VO_{2max}, and a proficient running economy (4–7). Obtaining a high VO_{2max}, by itself, is said to be one of the biggest determinants and prerequisites of a successful aerobic athlete (8). However, this information can be difficult to assess when time or specialist equipment is not available (9, 10). Although human aerobic performance can be broken down into high VO_{2max}, ability to sustain a high VO_{2max}, and proficient running economy, canicross is unique, in which another variable is involved, the canine.

Synchronization occurs when two oscillatory systems adjust their behaviors to obtain a state of unison after some interaction (11). This concept is best understood when observing the relationship between horse and jockey. In the sport of horse racing, the jockey aims to decrease negative interactions in which the horse must expend additional energy in order to continue the desired movement (11, 12). If the jockey can display a more elastic force on the horse comparatively to a rigid force, unnecessary energy expenditure can be saved (11, 12). In canicross, these synchronized interactions between the human and canine may play a detrimental role in optimal performance or energy expenditure of the team. An additional unnecessary energy expenditure would likely elicit a faster time to fatigue in both the human and canine athletes.

Another human-to-canine interaction that may play a role on canicross performance is the mass ratio between the human and canine. Towing, or adding a horizontal force to an object being towed, will result in an increase in velocity of the towee, as long as the tower has a greater velocity and enough proportional mass (7). This interaction can be seen in adventure running when one team member is allowed to be "towed" by another member in order to decrease the slower member's time (7). In situations where the towee is lighter, comparatively to the tower, there is a greater magnitude of the towing force, resulting in an increased velocity (7). However, this interaction is unknown in regards to canicross performance.

The purpose of this study was to identify and assess the influences of several performance factors on a time trial canicross event. The analysis of human-to-canine synchronization and mass ratios, as well as canine and human experience levels were correlated to the timed trial performance. The results of this investigation will increase understanding of specific performance factors involved in canicross events. The researchers hypothesized that human-to-canine mass ratios and human-to-canine synchronization will have stronger correlations with race performance than experience levels. However, we do expect to see the optimal level of human-to-canine synchronization increase with the level of experience within canicross runners.

METHODS

PARTICIPANTS

Nineteen (9 males and 10 females) adult competitive canicross athletes competing in either Redpaw's Dirty Dog Dryland Derby (Pearson, WI, USA) or the Hateya Trail Run (Kenosha, WI, USA) volunteered to participate in this study (mean ± SD: human age = 39 yr. ± 8, human height = 1.74 m ± 0.11, human (towee) mass = 79.95 kg ± 18.80, canine (tower) mass = 27.60 kg ± 8.05, and human-to-canine mass ratio = 3.04 kg ± 1.12). All participants were recruited through advertisements with race officials, flyers, social media and word of mouth. Both the university's International Review Board and the Institutional Animal Care and Use Committee granted approval of this study (HS 17-888). Exclusion criteria included the all racers under the age of 18 and those who did not complete the event.

DATA COLLECTION

Upon arrival at the event, participants were asked to sign an informed consent and to complete a short canicross experience survey. Mass of both the human and canine participants were taken using a portable force plate (ACP-1033 AccuPower, Advances Mechanical Technology, Inc. [AMTI], Watertown MA) with both participants measured separately. Height of human participant was taken using a standard stadiometer (Ningbo Finer Medical Instruments Co., Zhejiang, China). After, the participants were then asked to prepare for the event in a normal fashion.

Before the canicross event began, a mixture of five standard camcorders recording at 30 – 240 Hz were set up on a tripod at various level gradient locations perpendicular to the race trail. During the event, cameras captured sagittal plane footage with a panning view as the participants ran past. This footage was then saved and later uploaded into an automatic digitizing software (Kinovea, Version 0.8.15, www.kinovea.org) for data analysis.

DATA ANALYSIS

Synchronization

After data were uploaded to the automatic digitizing software (Kinovea), footage was standardized to 30 Hz for further data processing. During data processing, a standard time of one second (30 frames) was chosen and the gait phases for both the human and canine were mapped at each frame. Mapping of these phases were identified versus time in a longitudinal fashion. Human and canine flight phases were identified as a horizontal line, above the horizontal base line indicating contact phase. Within contact phase, a box was placed through the horizontal contact phase line, which identifies when the participant was in mid-stance (Figure 1).

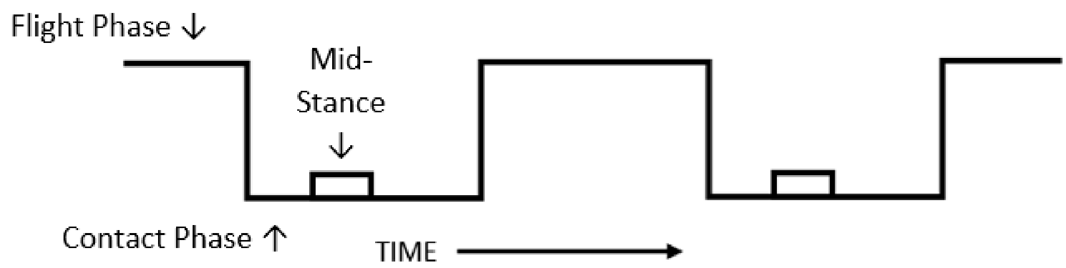

Figure 1: Example of Human and Canine Synchronization Mapping.

Flight was defined as when there was no contact with the ground. Whereas braking was defined as the phase from first ground contact until mid-stance, with mid-stance being defined as when the shank was directly over the lateral malleolus or when the stifle joint is directly above the paw. Propulsion was defined as the period from mid-stance to toe-off (Figure 2).

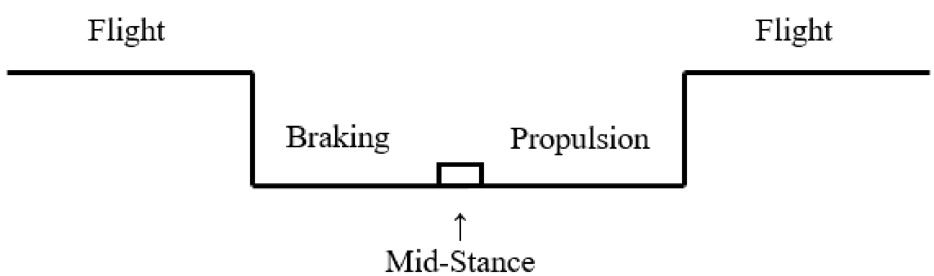

Figure 2. Example of Phase Definitions in Synchronization Mapping.

After completion of mapping, numerical values were assigned to each gait phase. Propulsion received the numerical number of one (1), mid-stance and flight, received a number of zero (0), and braking received a negative one (-1). These numbers were assigned according to predicted horizontal propulsion contribution of that stance phase. Since propulsion contributes to a forward horizontal force, this was indicated with a positive number, whereas braking decreases the forward horizontal force provided to the athlete so a negative value was assigned (13, 14). Mid-stance and flight were given the number zero as it was thought not to increase, nor decrease, forward horizontal propulsion. Due to the wide variety of different gaits exhibited within canine athletes, all four legs were mapped throughout.

Each frame that was mapped for both human and canine athletes and was then given the numerical value based on the identified gait phase. The synchronization maps for both human and canine were arranged in accordance to the corresponding time determined for each team. Synchronization mapping was arranged so one column identified a specific time for all synchronization mapping (Figure 3), this will be referred to as a frame column. Additionally, each frame column was then given a summed value, which indicated the synchronization of human and canine for that one frame. The total sums for each frame column were then added together to obtain a total synchronization score (Figure 3). This was done for every team at each location, where a higher synchronization score indicates better synchronization.

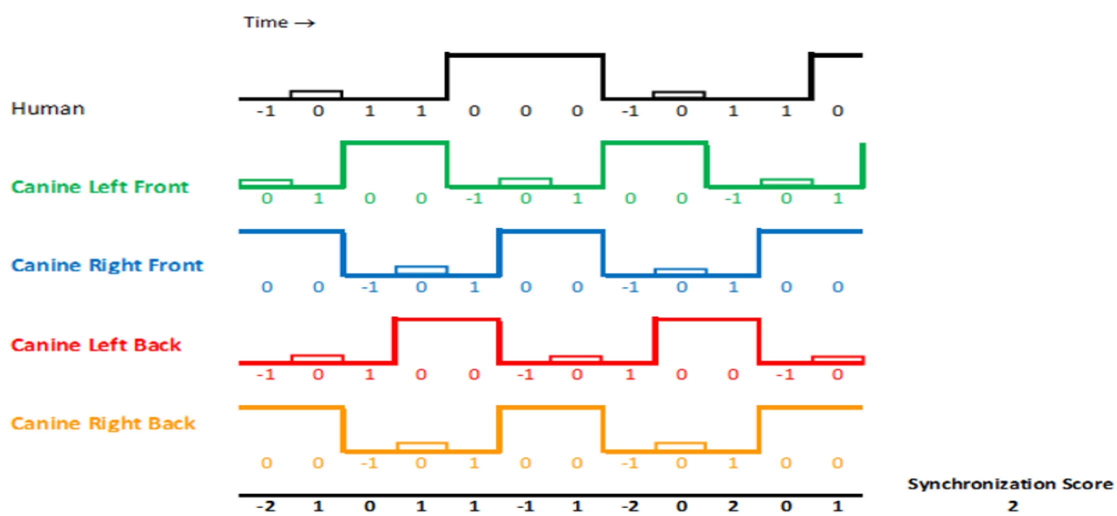

Figure 3: Mapping and Computing of Synchronization Scores.

All data that did not meet the standard one-second time (30 frame) requirement with ample data for all human and canine limbs were omitted at that location due to the differences seen in scores with less frames.

Temporal Gait Characteristics

Temporal gait characteristics were determined for each human and canine participant. Each stride, that was mapped previously, was divided into gait individual phases (flight, braking, mid-stance and propulsions). The percentage of time in each phase was calculated using the number of frames found in the synchronization map divided by the total amount of time for that stride. The percentage of time spent within each phases, were then averaged by stride, location, and the overall number of strides. This was used to determine the average percentage of time spent in each gait phase. The overall values were used later in statistical analysis.

STATISTICAL ANALYSIS

Correlation analysis (SPSS v.24) was used to identify relationships between all independent variables ($p<0.05$). A multiple linear regression analysis was used to predict time-trial performance based on human-to-canine mass ratio, synchronization, and human and canine experience level ($p < 0.05$). Additionally, a one way repeated measures ANOVA was used to determine differences in synchronization scores across locations. Mauchly's test of sphericity was used to identify whether sphericity can be assumed, before determining the F- statistic. Effect size was determined in relation guidelines for Cohen's d effect size where $d = 0.2$ is a small effect size, $d = 0.5$ is a medium effect size and $d = 0.8$ is a large effect size.

RESULTS

Three of the five video locations were used at each race event due to either clarity issues or technology malfunctions. Due to the two events differing in race distances, an average pace was used to compare race performance across groups where a faster pace indicated better performance. Table 1 displays the descriptive data for non-categorical performance variables. Table 2 indicates that over 62% of the participants in the current study have been running canicross for 2 years or less with only one participant (5.3%) running canicross for more than 10 years. Sixteen participants (84.2%) owned the dog they were using in the canicross event (Table 3). However, none of the dogs used in these events normally ran in the team or wheel position for other dog powered sports (Table 4). Table 4 indicated that 68.4% (n=13) of canine participants did not participate in other dog powered events besides canicross. If they did compete in other dog powered events, 21.1% of the dogs normally ran in the lead position and the other 10.5% usually ran in the swing position. Table 5 indicates that 11 of the 13 participants who did not compete in other dog powered events competed in the Hateya Trail Run.

A Spearman correlation revealed no significant correlation between any performance variables and the synchronization score at location 2 (Table 6). Location 1 synchronization scores were significantly, positively correlated with human-to-canine mass ratio ($R = 0.736$, $p < 0.01$) and the time trained without the dog in hours ($R = 0.809$, $p < 0.01$) (Table 6). Location 1 synchronization had a significant negative correlation to human age ($R = -0.720$, $p < 0.01$), the number of years owning the dog ($R = -0.604$, $p < 0.05$), and overall human braking ($R = -0.611$, $p < 0.05$) (Table 6). Table 6 also illustrates that location 3 synchronization score had a significantly positive correlation with the time trained with the dog in hours ($R = 0.778$, $p < 0.05$), but a significantly negative correlation with normal dog position ($R = -0.760$, $p < 0.05$) and overall percentage of time spent in human flight during an average stride ($R = -0.690$, $p < 0.05$).

A one way repeated measures ANOVA was used to compare synchronization within locations. Mauchly's test of sphericity indicated no violation of sphericity ($p = 0.275$), however there were no significant results found within the locations where $f(2,8) = 2.884$, $p = 0.114$, effect size = 0.419. Although the one way repeated measures ANOVA was not significant, location 3 tended toward having a lower synchronization score (Table 7).

The only performance variables that were significantly correlated with average pace of the canicross team were gender ($R = -0.603$, $p < 0.01$), time trained without dog in hours ($R = 0.613$, $p < 0.05$), dog position ($R = 0.654$, $p < 0.01$), and location 3 synchronization score ($R = -0.672$, $p < 0.05$) (Table 8). Gender had a significant negative correlation to the $p < 0.01$ level, indicating that males had a significantly faster average pace over females (Table 8). Location 3 also had a significant negative correlation indicating that the lesser the synchronization score in location 3, the faster the average pace (Table 8). Table 8 also indicated a positive relationship between time trained without the dog in hours, dog position, and average pace. Dog position had a significantly positive correlation indicating that those who had canines who competed in other dog powered sports, displayed a tendency toward having a faster average pace (Table 8). Table 9 indicates various other performance factors that were correlated with each other. Table 10 displays Spearman correlation data for relationship between human-to-canine mass ratio, where only location 1 synchronization score was significantly correlated ($R = 0.736$, $p < 0.01$).

Table 11 indicates the independent variables that were most representative of the dependent variable, average pace, in the stepwise regression. Overall percentage of time of the canine's left front foot spent in flight, being the most representative with the overall percentage of time the human spent in mid-stance, through an average stride, contributing in model two. Overall canine left front flight, and overall human mid-stance and human age were added to the equation with no other variables being removed or added at any point (Table 11). Table 11 also indicates the coefficient of determination (R^2) to be 0.929 for overall canine left front flight and 1.000 for overall human mid-stance. The coefficient of determination change (R^2 change) was again above 0.01 for both overall canine left front flight and overall human mid-stance, meeting requirements to be included in the regression equation, however this was not met by human age excluding it from the regression equation.

Table 12 indicates the unstandardized beta coefficient from which the regression equation was made. With Table 13 indicating the equation used in model two was significant at the p<0.01 level. Using model two the regression equation would be:

$$\begin{aligned} &Average\ Pace\ (m/s) \\ &\qquad = -9.954 + 0.271(Overall\ Canine\ Left\ Front\ Flight) \\ &\qquad - 0.286(Overall\ Human\ Mid - Stance) \end{aligned}$$

DISCUSSION

The purpose of this study was to identify and assess the influences of several performance factors on a timed trial canicross event. The results of this study found that there were significant correlations between average pace (race performance) and gender, time trained without the canine in hours, dog position, and synchronization at location 3. This evidence supports the findings by Barnes et. al. (4) and Jones et. al. (15), suggesting that those who spent more time in training, even as little as three weeks, could elicit a higher VO_{2max} which in turn could help prolong the effects of fatigue. The current study also indicated that those owning canines that compete in other dog-powered events tended toward having a faster average pace than those who competed with a household pet. However, all of the participants who had a dog that competes in other dog powered events, such as snow races or other dryland events, ran in the Redpaw's Dirty Dog Dryland Derby event. This is specifically worth noting because of the differing distances between these events. Hateya Trail Run had a distance of 6.44 km in length, where Redpaw's Dirty Dog Dryland Derby was 2.41 km in length. Therefore, although there was a significant correlation between dog position and average pace, this could simply be due to the shorter distance of the event.

Another interesting finding is the negative correlation found between location 3 synchronization score and average pace. This indicates that the lower the synchronization score at location 3, the faster the average pace. A possible explanation would be that at both events the camera in location 3 was placed less than 1km from the finish line. If the participant were to change their running pattern, due to a sprint to the finish, this synchronization score would likely decrease. With an increase in running speed, the canine may switch from a walk or an amble gait, in which there is always contact with ground, to a trot or suspended gallop. This change to a greater amount of suspension gait would likely decrease synchronization sum, due to flight having a value of zero. Likewise, if the participant started their sprint to the finish prior to the third camera, the score would likely be less for the same reasons. However, yet another caveat to this finding is the method of scoring synchronization.

Synchronization scoring was based on the idea that adding a forward horizontal force would contribute to more assistance for the human athlete and would in turn elicit a faster pace (13, 14). However, optimal synchronization in a canicross system has never been previously evaluated; therefore, this scoring is simply theoretical. In the current study, a high synchronization score would be obtained through the human athlete being in propulsion and multiple canine limbs in propulsion at the same time, at many different frames. Therefore, if true optimal synchronization would be anything different, such as human athlete in flight as the canine is in propulsion, the current synchronization score would not accurately represent it. The lack of correlation between synchronization score and average pace (the performance variable) may suggest that synchronization scoring is flawed when trying to detect optimal performance. This may be due to the inaccurate weighting of the performance influences. Since the regression analysis revealed performance was highly influenced by overall canine left front foot flight and overall human mid-stance; weighting those factors higher than others may lead to a synchronization score that reflects optimal performance. Another variable to consider in the synchronization scoring is that the current study weighted the overall score for the canine four times higher than that of the human due to the addition of all canine legs in the scores. It is likely that weighting the canine less, would also drastically effect the synchronization scores. Further studies might evaluate synchronization based on the highly influencing components of overall performance in place of predicted forward horizontal force assistance.

Although possible flaws in synchronization scoring, all scoring was standardized with indications of temporal gait characteristics. Results from the one way repeated measures ANOVA, indicated no significant synchronization score differences across locations, but location 3 tended toward having a lesser synchronization score (Table 7). This would support the idea that as the participant was within 1km of the finish, there were changes in running patterns where a sprint to the finish could contribute to decreasing the synchronization score. Because there was no significant difference between synchronization scores across locations, these results may also indicate that the human and canine have reached their optimal team synchronization at location 1 and held that synchronization throughout the race. Another possibility is that because of the low number of participants that had sufficient data to analyze synchronization scores ($n = 5$), these findings may not fully reveal the interaction between human and canine as the event progresses. Further research should be done to evaluate how synchronization is influenced across a canicross event.

A result that surprised the authors, human-to-canine mass ratios were not significantly correlated to the average pace of the canicross system. These findings are slightly different when compared to Graboski and Kram (7) who examined adventure running and found significant increases in the benefits of towing when the mass of the tower was increased. The differences in findings can likely be contributed to the mass of the tower. Where if there was a dramatic increase in canine mass, there would also be an increase in the benefits of towing as seen by Graboski and Kram (7).

The mean mass ratios displayed in the current study were 3.04 kg ± 1.12 with an average tower mass of 27.60 kg ± 8.05 and an average towee mass of 77.95 kg ± 18.80.

Whereas the study by Graboski and Kram (7), had an average tower mass of 68.25 kg ± 12.05. This drastic difference in tower mass could be why the current study had no significant findings in human-to-canine mass ratios on performance. Additionally, when a human athlete is being towed by another human athlete, the line of tow is more horizontal when compared to being towed by a canine athlete. When the canine is towing the athlete, the horizontal force the canine is exhibiting on the human, is less than the force in the gangline because of the angle of the tow, which is influenced by the height of the canine and the length of the elastic gangline. Because of this increase in tow angle, the force being produced by the canine is not as effective in producing forward horizontal force as a human tower. Therefore, it may be beneficial to compete with a canine who is taller and with the longest, within restrictions, length line in order to increase the tow angle when compared to a shorter canine and line length.

An additional unexpected finding is the lack of correlation between experience level and human-to-canine synchronization scores. This finding would suggest that whether it is your first race, or you have been competing in canicross for years, there is no learned synchronization that occurs through years of practice. However, this study only examined years the human athlete had been running canicross, it did not examine how long the canine had been running or how long the team had been running together. Future research should investigate all three variables of experience level.

The regression analysis revealed that there was a significant equation for predicting average pace using the overall percentage of time the canine's left front foot spent in flight and the overall percentage of time the human was in mid-stance throughout an average stride. From this regression, a higher overall canine left front foot propulsion would indicate better performance of the canicross system. This would also suggest that the speed of the canine would be quicker in those who had a better overall performance. Because one of the canine variables was one of the main predictors of performance, we can confidently assume that the canine contributes substantially to the overall performance of the system.

A limitation in the current study is the high variability between canicross athletes and the experience levels of the canicross teams. Although both events were considered competitive races, the Hateya Trail Run event drew more recreational canicross athletes in comparison to Redpaw's Dirty Dog Dryland Derby. This became evident when mapping the canicross systems and comparing the amount of time the canine was propelling the human athlete. Other large limitations in this study was the differences in race lengths and the number of participants that had sufficient video data to compute synchronization scores at all events. Because of the differences in race lengths, average pace was used as the performance determinant. This is slightly flawed because those competing in the longer event could be using a different pacing strategy when compared to those who ran in the shorter event. As stated previously, another limitation may be in the calculation of the synchronization scores. In addition to possible discrepancies in how to calculate optimal synchronization as stated earlier, weighting of synchronization summation could differ in two limbs (average synchronization back) compared to the four (average synchronization sum).

Finally, terrain could also play a large role in synchronization scoring. Although all cameras were placed on a seemingly flat area of the trail, at least one camera in each race (camera two in both events) had to be placed after a hill in order to obtain enough footage. It is probable that as human gait patterns change, the synchronization scores would also change. This is of interest particularly because variations in gait could also be due to the terrain of the event; where different environmental and trail conditions could lead to alterations in gait. It is currently unclear how changes in terrain would affect the synchronization score in terms of helping or hindering, therefore further studies need to be done.

In summary, there were several significant correlations found as indicators of race performance. Where the amount of time trained without the dog and normal dog position were positively correlated with performance. While the gender and synchronization scores at location 3 were negatively correlated indicating that males and those with less synchronization toward the finish, according to the current study's scoring method, could be telling of overall performance. However, human-to-canine mass ratio was not significantly correlated to performance as hypothesized. Synchronization scores across locations were not significantly different indicating that the canicross system (human and canine) held the same synchronization patterns throughout the event. A regression indicated that performance can be predicted using overall canine left front foot flight and overall human mid-stance. Unfortunately, due to the differences in distances between the events and the methods of scoring, the results may not be as telling of canicross performance as the authors had originally anticipated. Future research should continue to investigate optimal synchronization patterns in high-level canicross athletes. Further investigation should also evaluate the experience level of not only the human athlete, but also the canine and the experience of the system.

CHAPTER II: LITERATURE REVIEW

The purpose of this study is to identify and assess the influences of several performance characteristics during a timed trial one dog canicross event. The purpose of this review is to give a general background and insight to the sport of canicross, as well as, discuss important variables related to this unique sport. This literature review will be separated into the following sections: (a) brief background on the sport of canicross; (b) identifiers of human performance; (c) human-to-canine interaction within the sport; and (d) canine performance factors.

CANICROSS

The utilization of sled dogs dates back to the early 1800s, where they were used to haul supplies that was otherwise inaccessible due to snow and extreme weather conditions in the northern regions (1). These dogs were bred to have great endurance and strength to help them pull hundreds of pounds of supplies through the dead of winter (1). Throughout the years, sled dog racing has taken the place of the traditional sled dog uses and has become a current recreational and competitive sport.

Sled dog racing is most popular in the northern regions of the world (Alaska, Canada and Europe), where the traditional purposes of sled dogs can still be utilized (1). However, the sport has changed and adapted within the past number of years. Mid-distance (40 - 440km), sprint (anything less than 40km) and even dryland races are added as types of races along with the traditional long distance, endurance races (441 – 1,800 km), such as the Iditarod (1). Although these events are all very different when considering tactics and training, the basics are similar; cover a set distance in the shortest amount of time.

Dryland racing is best described as a sled dog race without snow. In this sport, mushers, or the human participant in the team, use wheeled rigs and/or movement on foot to complete the race (2). These races are typically held in late fall or early spring and are much shorter than traditional winter events. Typically, some sort of dryland training or racing is used by most mushers as preparation for the upcoming snow season, however some mushers compete solely in dryland racing, as you need much fewer dogs to compete (2). An event in dryland racing, popular in Europe, is canicross (16). Canicross is similar to skijoring, where a one or two dog team pulls the human athlete as they run behind. The human athlete will typically wear a harness attached to an elastic or bungee gangline (the rope connecting the human to the canine) to reduce the shock between human and canine (Figure 4) (2).

Figure 4. Diagram of Canicross Adapted from iStock (17)

In most recent sled dog participation demographics, in the Midwest there is a pretty even split of participants (n=385) who are male (58.2%) and female (41.8%) (18). In this published survey sled dog athletes by Steele (18), 94.0% of respondents competed in sledding and 38.8% of respondents competing in carting or rig racing. Additionally, 6.3% of respondents competed in canicross (18).

Although canicross is still a growing sport, the participants of the sport have been dramatically understudied (3). Canicross is considered a team sport in which the human athlete and the canine must work together in order to complete the event. Currently, there is no research identifying or assessing performance characteristics of human or canine within this sport. Identification of these performance characteristics, consideration of the human athlete's performance, the canine's performance, as well as the team of human and canine should be considered.

HUMAN PERFORMANCE

A successful aerobic runner usually has three physiological characteristics that contribute to their performance. These characteristics are: high maximum oxygen uptake (VO_{2max}), the ability to sustain a high percentage VO_{2max}, and a proficient running economy (4–6, 19).

Maximum Oxygen Uptake

VO_{2max} can be defined by the athletes volume of maximal oxygen uptake (6). However VO_{2max} is influenced by factors such as muscle capillary density, stroke volume, and the predominate type of muscle fibers found within the athlete (19, 20). Alone, this factor has been shown to be one the biggest determinants and prerequisites of a successful aerobic performance athlete (4, 8, 15, 21). VO_{2max} is highly trainable through moderate to high intensity aerobic training programs in as little time as three weeks (4, 15, 22).

The best, and most frequently utilized method to measure VO_2 is in a lab using a gas analyzer, where the exact amount of oxygen gas is measured along with the volume of exchanged oxygen and carbon dioxide (23, 24). This test can give athletes a better understanding of their aerobic capacity, where the larger the aerobic capacity, the better performance in endurance type sports (15). Unfortunately, this aspect can be difficult when time or equipment is not available in the field. A solution to this problem would be the consideration of various field tests to estimate the aerobic capacity such as the 1.5 mile run/walk test (10, 23, 24). This field test can test a number of participants at a time and can be individualized as the participant sees fit. From this field test, a simple calculation can approximate a VO_{2max} value (10, 24). This test has been deemed valid and reliable on multiple occasions (9, 23–25).

However, this field test is not 100% foolproof. Problems associated with using any field tests would include the approximation of VO_{2max} (10, 24). If the participant was not giving a full effort, or is not fully recovered from previous activity, this will play into the validity of the test (10, 24). Another downfall of this test is the instructions to "give a maximal effort" or "run as fast as possible" (10, 24). These instructions may result in increased injury and cardiovascular risk within untrained individuals (7, 24). However, because this aspect is so important in any aerobic performance event, special consideration should be taken when trying to identify performance aspects in sports such as canicross. All in all, the benefits of having an approximate VO_{2max} would outweigh the risks in this trained population.

Running Economy

Running economy can be defined as the energy demand required at a given submaximal velocity, determined by measuring steady-state oxygen consumption (26). Where the less energy demand to run a certain speed is considered having good economy or being more efficient (27). Although, running economy and running efficiency are seemingly different categories, they tend to interplay with each other quite well. Running economy is measured at a constant velocity whereas running efficiency is measured by how much caloric expenditure is utilized compared to the output of work (27). To put it simply the more efficient you are, the higher economy you will have which in turn leads to less energy expenditure (27). This variable would be especially helpful when comparing elite athletes, who have similar VO_{2max}, where differences in running efficiency and running economy could determine the winner from the loser (4, 6, 26).

One way that efficiency plays into economy is through stride length and frequency (27). When trained, elite runners are looking to increase running velocity, they train to increase either their stride frequency or their stride length (27, 28). However, in most cases, they also increase the energy expenditure, in turn decreasing the efficiency of the runner (27). When a natural stride length is used, it has been shown to be the most economical (26, 29, 30).

A way that is used to train stride frequency and stride length is by using a technique that involves elastic-cord towing (31, 32). This overspeed exercise is used as a training modality to help athletes achieve greater stride length and stride frequency (31–34). With implementation of elastic cord towing, there were significant increases on running speed, stride length and ground contact time (31, 32, 34). Furthermore, the optimal body weight assistance, was exhibited by the elastic cord when the towing force was 30% of the runner's body mass (31). However, in all studies, these effects were only investigated on sprint athletes, where the longest sprint event observed was 100-m (31–34). It is still unknown if these effects will carry over into distance running.

In canicross, an increase in stride length or stride frequency of the human participant would result in the benefit of increased running velocity, which in turn will increase energy expenditure (26, 29, 30). Unlike in other running events, canicross is unique in the way that there is another variable involved, the canine. If the canine were to help the runner obtain an increase in stride length or frequency, the human participant could complete the event faster than if they were competing alone. However, this interaction can only occur with optimal synchronization between human and canine.

HUMAN AND CANINE INTERACTIONS

Synchronization

Synchronization occurs when two oscillatory systems adjust their behaviors to obtain a state of unison after some interaction (11). This concept is best understood when observing the relationship between horse and jockey. In the sport of horseracing, the jockey's job is to keep the horse at the highest speed throughout the racetrack, while minimizing the impact of energy expenditure the jockey places on the horse. With the added mass of the jockey placed on the horse, the horse will now have to work harder (increasing the energy expenditure) in order to maintain a given velocity (11). The jockey can have further influence on this based on the type of force he exhibits on the horse. If the jockey is out of synch or places a rigid force on the horse compared to that of an elastic one, the energy expenditure of the horse will increase resulting in a quicker decrease in velocity (11, 21). A more elastic force (in synchronization) compared to a more rigid one (not in synchronization), will either lessen or exacerbate the amount of energy the horse will need to expend in order to keep that velocity, respectively (11, 35).

In canicross, it is possible that if human and canine athletes were able to attain an optimal synchronization, there may be benefits such as decreased energy expenditure and possibly some increases in stride length and frequency because of the towing effect. However, because of the lack of research on the synchronization aspect of the sport, this is still unknown. Although this synchronization pattern would not matter if the line between human and canine were not taut. If the line is loose, the human and canine are essentially two separate systems in which it does not matter what the synchronization is because the canine is not assisting in propulsion. In that case, the system would rely strictly on the performance of each athlete separately.

Human-to-Canine Mass Ratio

Human mass has previously been correlated to performance in sports like endurance running and cycling where an increase in body mass could be a detrimental factor of performance because the human must exert energy in order to move their mass (7, 8). Similarly, the higher the mass placed on the horse in a horse racing scenario, as stated earlier, the greater the energy expenditure the horse must exhibit to maintain velocity (12). Because of this interaction, jockeys typically want to weigh as little as possible. However, what if we change this interaction?

The theory behind towing, or adding a horizontal force to an object or human, is that the object being towed will have an overall greater velocity than if the object were moving by itself (7). This interaction is understood best in adventure running, where the team's overall place is determined based on the combination of time to complete the course. In adventure running, one member of the team is allowed to be "towed" by another member in order to decrease the slower member's time (7). A study by Graboski and Kram (7), found benefits of towing when the towee is comparatively lighter than the tower, which created a greater towing force.

This same study also identified the percentage of gain one could experience in using this idea of towing. The additional horizontal towing force exhibited an improved time of 15% over the course of 10km, when optimal towing was used (7). Where optimal towing was calculated using each runner's solo performance time, distance traveled, VO_{2max}, $VO_{2submax}$, percentage of VO_{2max}, and body mass (7). However within this relationship, a towee mass of over 15% of tower mass may cause a potentially increased risk of injury in the tower (33).

Within canicross, when choosing a canine to compete with, it may be beneficial to consider the mass of the canine that will be providing the towing force. Not only for the benefit of utilizing as much tow force as you can, but also to gain the potential increase of stride length and frequency through the help of the towing force. Where having a larger canine may lead to an increase in advantages in both areas.

CANINE PERFORMANCE

Canine Experience

Much like humans, the canines in any sled dog event will also need to display adequate fitness or VO_{2max} in order to complete the event and demonstrate high performance level. Canines are specifically chosen and trained by the human athlete to achieve a fast pace, while also having the strength to pull the sled, cart or other mode of human transportation (1). Through appropriate training experienced distance sled dogs are able to cover over a thousand miles in a little over a week (1).

Within the sport of sled dog racing, different positions on the team are considered to have different attributes that help the team in completing the race. Lead dogs (Figure 5) are one of the most important positions within a sled dog team (36). The lead dogs are responsible for keeping the pace of the team as well as obeying commands of the musher in order to turn the team (36). The swing or point dogs have the responsibly to swing the rest of the team around the turn in order to make the turn successfully. The team dogs responsibilities include maintaining the speed set by the lead dogs and contributing to pulling the sled, rig and/or human athlete (36). Wheel dogs also have an important role in team, as these dogs are the dogs that contribute the most to the pull of the sled (36). These dogs tend to be your biggest and most levelheaded dogs as they also deal with a large amount of the jarring from the sled (36).

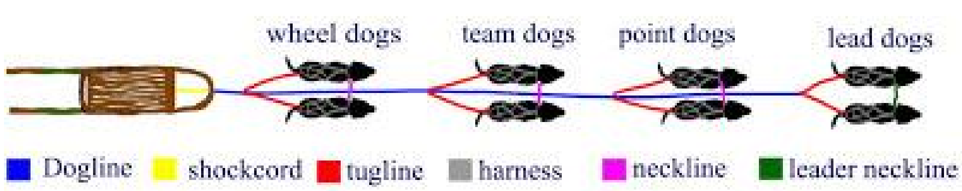

Figure 5. Sled Dog Positions (34)

Traditionally in the sport of canicross, lead dogs are predominantly used because of the one-on-one training the musher can give to the dog. However using a larger dog with more pull force may be beneficial in the horizontal or forward propulsion of the human athlete. On the other hand, if the dog does not have leading experience, pacing may not be the canine's strong point which could ultimately cause a decrease in overall performance.

Canine Fitness

Although, it is likely a guarantee that the canine will be able to out run the human athlete, it is probable that this is still an important aspect of the team's performance. Like humans, all animals can become untrained and will need to re-gain their aerobic capacity. However, endurance trained Alaskan Huskies have been found to have VO_{2max} values as high as 240 ml/kg/min (37). This value is significantly higher than previously suspected based on the body mass specific VO_{2max} prediction for mammalian species (37). However, household canines have been seen to have a VO_{2max} value as low as 30 ml/kg/min (38). This is likely due to the inconsistency or low frequency of exercise.

Although previous studies have indicated that there are significant training adaptions that occur during moderate intensity training, it is likely that the average house dog will not achieve such high VO_{2max} values (38). This aspect would be important because the fitness of the canine could play a crucial effect on whether they are able to help in propulsion throughout the event or if they are lagging behind. However, most canines will be well above their human counterpart in terms of VO_{2max}. Therefore, this aspect of performance is probably not as important as other variables found in a canicross system. And if the canine does fall into the low range of VO_{2max}, moderate training has been shown to significantly increase this value with moderate intensity training (38).

Canine Velocity

The maximum velocity the canine can obtain may play an influential role on the overall speed of the canicross system. Greyhounds are one of the fastest, if not the fastest dog breed known to man (39). One of the main differences found in greyhounds are the overwhelming amount of fast twitch muscle fibers when compared to other canine breeds (39). This, much like in humans, will have an effect on the speed and distance that these animals are able to complete. Fast twitch muscle fibers are able to produce force quickly but not for long lengths of time, whereas slow twitch muscle fibers are not able to produce as much force but they fatigue slowly. Greyhounds, although fast, are only able to run extremely fast for a very short period of time. A typical greyhound race is 502.92 m in length, which is drastically shorter when compared to an average sled dog event on snow (1, 40). Conversely to the greyhound, the Alaskan husky is a predominately composed of slow twitch muscle fibers (41, 42). Alaskan huskies are seen a great deal in distance sled dog racing for this reason. They are able to endure these long distances, partly because of their muscle fiber composition. In canicross, due the distance of the event, it is likely that a canine breed with both fast and slow twitch muscle fibers would have the most advantage. Both for covering a distance as quickly as possible but also having the effect of prolonged fatigue.

Another finding by Hudson and colleagues (39) found that a limitation to top speeds may be linked to the amount of peak limb force the animal is able to withstand. During the propulsion phase of the canine, vertical impulse is influenced by the animal's body weight and its stride length (39). Impacts of above that which the canine can withstand will limit the velocity at which the canine can travel. Their study showed that as the speed of the canine increased, both hind limbs showed increases in peak limb force, while vertical impulses remained constant (39). This is similar to what we see in human runners, where peak vertical ground reaction forces increase as a runner increases velocity, but the impulse decreases or remains the same (35, 43, 44).

From this research, it is believed that in order for canines to achieve top speeds, a composition of fast twitch muscle fibers and the ability to produce and withstand a large amount force in the hind limbs is crucial. Where a canine who is able to withstand a higher peak impulse and is able to generate that force quickly and rapidly, would have the ability to run faster. This lines up directly with our knowledge of fast twitch muscle fibers, where dogs with more fast twitch muscle fibers would have the capability to run faster when compared to another breed who has predominately slow twitch muscle fibers. That being said, because of the fiber type characteristics and the varying distances among canicross events, canines with predominately fast twitch fibers will likely excel in shorter events, where canines with predominately slow twitch fibers will excel at the longer events.

Canine Strength and Gait

As stated above, speed is a crucial aspect to canine performance in a canicross event. The canine must be fast in order to obtain the fastest overall time, but the canine must also be strong in order to propel the human athlete through the course. In relation to propulsion forces, in traditional sled dog racing (with a sled) when a one dog team is used, the canine may be required to pull up to 100% of the weight of the sled (45). However when a two dog team is used, each canine may be required to pull up to 85% of the weight of that mass (45). Harness vectors plus the resulting torque of the sled will create this inefficiency of distributed work in a two dog team (45). Although different in the aspect of canicross where the canine will not be required to pull 100% of the "load", the pull force by the canine on the human athlete is decremented by the line of tow. Because the line of tow from the canine to the human in a canicross event results in an increased downward angle when compared to a human tower, forward horizontal propulsion may be compromised. In order to achieve an optimal forward horizontal tow, the canine would have a long leg length and gangline. However, even with an optimal tow angle, it will still be ineffective if the canine is not pulling.

Canines have distinct gait patterns based on the speed they wish to obtain. Faster speeds are obtained through galloping gaits, where a propulsionary flight phase is seen either once or twice depending on the specific gait (46). Body size can influence gait to a point, where the stride length of all canines will depend on their size and shape; for example longer canines will have a naturally longer gait patterns (45). However, gaits in which a flight phase takes place may be detrimental to the propulsionary force needed to pull the runner (45). These flight phases make the propulsion ineffective, therefore good pulling dogs usually exhibit a loping or a galloping gait, with no flight phase (45, 46). That being said we see a sacrifice in speed in order to achieve that. However, a major limitation in the previous study, is that this work only looked at sled dogs working in a team of two or more (45). Competitive canicross dogs usually work alone or in teams of two, this can be difficult for some dogs especially if not accustomed to running in front of their human athlete or not habituated to pulling.

SUMMARY

Canicross is a training modality in dog sled racing which takes place during the late fall or early spring training season traditionally in preparation for the winter sled dog season (1, 2). Although no current research has identified performance factors within canicross, we would expect event success comes down to the combination of human performance factors, canine performance factors, and the interactions between human and canine.

Human fitness levels have been shown to be one of the main contributors in traditional aerobic running events, where identification of VO_{2max} can give strong indications of an athlete's aerobic performance (4–6, 8, 15, 19, 21). Although hard to collect when in the field, other field tests can be used in order to approximate a VO_{2max}, such as the 1.5 mile run/ walk test (9, 10, 23–25). Another human performance characteristic would include running economy (4–6, 19). This characteristic seems to be most influential when identifying differences between athletes with similar VO_{2max} and includes the interplay of efficiency (4, 6, 26). Running efficiency has been shown to be somewhat trainable through training drills with elastic-cord towing, although all research has only been done on sprint athletes (31–34).

However, the same concepts of elastic-cord towing, may apply to the canicross team when speaking in terms of human-to-canine synchronization and mass ratios. Synchronization occurs when two oscillatory systems adjust their behaviors to obtain a state of unison after some interaction (11). If the canicross team can achieve optimal synchronization, improvements in both energy expenditure and stride length could potentially be attained. With the appropriate human-to-canine mass ratio, a greater tow force may be provided to the human athlete. Achieving the optimal tow force of 30% of human body mass could be beneficial to the human athlete as found by Bartolini and colleagues (31) on women soccer players using a sprinting model. It is currently unknown if this value for optimal tow force would transfer over to a canicross system.

Canine experience level can also play a part in the determinant of performance. Traditionally, canicross was used to train lead dogs because of the one-on-one attention the musher can give the canine. However, with the growth of the sport, even household canines are being used (18). The use of a household pet may be disadvantageous depending on the fitness level of the canine. Trained sled dogs have been found to have a VO_{2max} value of 240 ml/kg/min, where untrained household pets average around 30 ml/kg/min (37, 38). Canines with a lesser VO_{2max} value may lag behind or not contribute fully to the horizontal forward assistance the canicross runner would need. This detriment in canine VO_2 would also compromise the velocity and the length of time the canine provides propulsive contribution in the longer distance events. This could potentially lead to decreases in the performance of the canicross system. However, if the same canine who had a lesser VO_2 but was able to complete the event quickly before they hit fatigue, they would likely excel in the shorter events. Nevertheless, the experience level along with the size and the selected pace and gait of the canine may potentially provide some added benefits.

All in all, no one variable within canicross running can tell the whole story. Further identification and assessment of all performance variables should be investigated in future studies.

CHAPTER III: CONCLUSIONS AND RECOMMENDATIONS

Prior to the current study, canicross had been drastically understudied with very little information indicating variables of high performance. The current research investigated various potential performance factors in order to identify which factors had the strongest relationship with overall performance. Results of the current study determined the more hours spent in training without the canine, using a canine that competes in other dog powered events, lesser synchronization scores when approaching the finish and gender, were the variables most related to performance. Although optimal synchronization has yet to be determined in the sport of canicross, synchronization scores within locations were not significantly different, indicating that a synchronized rhythm between human and canine was established early in the event and continued throughout. Although synchronization tended toward a lower score at location three, the difference was not significant. The lower synchronization scores were attributed to changes in human running patterns, likely caused by a sprint to the finish. However, the lack of participants that had sufficient data (n = 5), makes these findings difficult to extrapolate out to the general canicross population. Limitations to the study included the differences between lengths of race events and probable flaws in synchronization scoring. Because of the differences in lengths of the events, average pace was used as the performance variable. This would lead to probable errors due to different pacing strategies when competing at different events. Synchronization scores were established based on the idea that an addition of forward horizontal force would be beneficial to overall performance time;

however current synchronization scores were not significantly correlated with the performance variable. This would indicate that the current method of tracking could not determine optimal synchronization. Future research should investigate additional methods of obtaining synchronization scores to determine an optimal synchronization for a canicross system.

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TABLES

TABLE 1. Descriptive Statistics (Mean and Standard Deviation) of Measured Non-Categorical Performance Variables

	Mean ± SD	**N**
Age (yrs.)	39.95 ± 8.39	19
Human Mass (kg)	77.95 ± 18.80	19
Human Height (m)	1.74 ± 0.11	19
Canine Mass (kg)	27.60 ± 8.05	19
Human to Canine Mass Ratio	3.04 ± 1.12	19
Average Pace (m/s)	3.18 ± 0.98	18
Time Owned Canine (yrs.)	3.03 ± 2.46	18
Time Trained Without Dog (hrs.)	32.27 ± 23.88	15
Time Trained With Dog (hrs.)	14.12 ± 17.43	17
Overall Human Braking	13.88 ± 3.86	16
Overall Human Mid-Stance	10.08 ± 0.73	16
Overall Human Propulsion	55.32 ± 8.60	16
Overall Human Flight	20.72 ± 5.68	16
Avg. Synchronization Score (Sum)	22.98 ± 6.45	15
Avg. Synchronization Score (Canine Back)	20.06 ± 5.30	15
Location 1 Synchronization	21.75 ± 7.88	12
Location 2 Synchronization	27.64 ± 7.40	11
Location 3 Synchronization	17.44 ± 7.92	9

TABLE 2. Frequency Data for Categorical Question “Years Running Canicross”.

	Percentage	**N**
First Year	31.6 %	6
0 – 2 Years	31.6 %	6
2 – 5 Years	10.5 %	2
5 – 10 Years	21.0 %	4
10+ Years	5.3 %	1
Total	100%	19

TABLE 3. Frequency Data for Categorical Question "Are You Using Your Own Dog?".

	Percentage	**N**
Yes	84.2 %	16
No	15.8 %	3
Total	100%	19

TABLE 4. Frequency Data for Categorical Question "What Position Does Your Dog Normally Run in Larger Teams?".

	Percentage	**N**
N/A (Does not participate in other dog powered sports)	68.4 %	13
Lead	21.1 %	4
Swing	10.5 %	2
Team	0 %	0
Wheel	0 %	0
Total	100%	19

TABLE 5. Frequency Data for Categorical Question “What Position Does Your Dog Normally Run in Larger Teams?” By Race Event.

		None or N/A	Lead	Swing	Team	Wheel
Redpaw’s Dirty Dog	N	2	4	2	0	0
Dryland Derby	Percentage	25%	50%	25%	0%	0%
Hateya Trail Run	N	11	0	0	0	0
	Percentage	100%	0%	0%	0%	0%

TABLE 6. Spearman Correlation Findings Between Synchronization Scores at Each Collected Location and Various Performance Variables.

		Location 1 Synch. Score	Location 2 Synch. Score	Location 3 Synch. Score
Human Age (yrs.)	Correlation Value	**-0.720****	-0.118	-0.167
	Significance (p)	**0.008**	0.729	0.667
	N	**12**	11	9
Mass Ratio	Correlation Value	**0.736****	0.092	0.077
	Significance (p)	**0.006**	0.788	0.845
	N	**12**	11	9
Years Owning Dog	Correlation Value	**-0.604***	-0.118	-0.302
	Significance (p)	**0.049**	0.745	0.467
	N	**11**	10	8
Time Trained Without Dog (hrs.)	Correlation Value	**0.809****	-0.398	-0.417
	Significance (p)	**0.008**	0.255	0.352
	N	**9**	10	7
Time Trained With Dog (hrs.)	Correlation Value	-0.530	0.125	**0.778***
	Significance (p)	0.094	0.715	**0.014**
	N	11	11	**9**
Dog Position	Correlation Value	-0.103	-0.492	**-0.760***
	Significance (p)	0.751	0.124	**0.018**
	N	12	11	**9**
Overall Human Propulsion	Correlation Value	0.445	0.447	0.613
	Significance (p)	0.147	0.168	0.079
	N	12	11	9
Overall Human Mid-Stance	Correlation Value	-0.453	-0.097	-0.077
	Significance (p)	0.140	0.777	0.843
	N	12	11	9
Overall Human Flight	Correlation Value	-0.301	-0.479	**-0.690***
	Significance (p)	0.341	0.136	**0.040**
	N	12	11	**9**
Overall Human Braking	Correlation Value	**-0.611***	-0.074	-0.256
	Significance (p)	**0.035**	0.829	0.505
	N	**12**	11	9

Blue * indicates significance to the 0.05 level (two-tailed)
Red ** indicates significance to the 0.01 level (two-tailed)

Table 7. Means and Standard Deviations of Synchronization Scores Across Redpaws's Dirty Dog Dryland Derby.

	Mean ± SD	**N**
Location 1	23.80 ± 9.94	5
Location 2	28.20 ± 7.95	5
Location 3	17.40 ± 8.88	5

TABLE 8. Significant Spearman Correlation Data Found Between Performance Variables and Average Pace.

		Average Pace
Gender	Correlation Value	**-0.603****
	Significance (p)	**0.008**
	N	**18**
Time Trained Without Dog (hrs.)	Correlation Value	**0.613***
	Significance (p)	**0.020**
	N	**14**
Dog Position	Correlation Value	**0.654****
	Significance (p)	**0.003**
	N	**18**
Location 3 Synch. Score	Correlation Value	**-0.672***
	Significance (p)	**0.047**
	N	**9**

TABLE 9. Various Spearman Correlation Findings Between Performance Variables.

		Time Trained With Dog (hrs.)	Human Years Running Canicross
Dog Position	Correlation Value	**-0.583***	**0.512***
	Significance (p)	**0.014**	**0.025**
	N	**17**	**19**
Time Trained Without Dog (hrs.)	Correlation Value	**-0.560***	0.079
	Significance (p)	**0.037**	0.780
	N	**14**	15

Blue * indicates significance to the 0.05 level (two-tailed)

TABLE 10. Spearman Correlations Between Mass Ratio and Synchronization Scores.

		Average Pace	Average Synch. (Sum)	Average Synch. (Canine Back)	Location 1 Synch.	Location 2 Synch.	Location 3 Synch.
Mass Ratio	Correlation Value	0.000	0.489	0.466	**0.736****	0.092	0.077
	Significance (p)	0.999	0.064	0.080	**0.006**	0.788	0.845
	N	18	15	15	**12**	11	9

Red ** indicates significance to the 0.01 level (two-tailed)

Table 11. Independent Variables Entered into the Stepwise Regression.

Model	Variables Entered	R	R Squared	Standard Error of the Estimate	R Squared Change	F Change	Significant F Change
1	Overall Canine Left Front Flight	0.964	0.929	0.320	0.929	26.257	0.036
2	Overall Human Mid-Stance	1.000	1.000	0.007	0.071	4479.378	0.010
3	Human Age	1.000	1.000		0.000		

Table 12. Unstandardized Coefficients with Coefficients Standard Error and Significance Level; Dependent Variable: Average Pace

Model		Unstandardized B	Coefficients Std. Error	Standardized Coefficient Beta	t	Significance
1	(Constant)	-11.341	3.046		-3.723	0.065
	Overall Canine Left Front Flight	0.247	0.048	0.964	5.124	0.036
2	(Constant)	-9.954	0.068		-147.223	0.004
	Overall Canine Left Front Flight	0.271	0.001	1.059	-250.910	0.003
	Overall Human Mid-Stance	-0.286	0.004	-0.282	-66.928	0.010
3	(Constant)	-9.568	0.000			
	Overall Canine Left Front Flight	0.266	0.000	1.040		
	Overall Human Mid-Stance	-0.301	0.000	-0.298		
	Human Age	0.002	0.000	0.028		

APPENDICES

APPENDIX A

NORTHERN MICHIGAN UNIVERSITY

RESEARCH STUDY- SCHOOL OF HEALTH AND HUMAN PERFORMANCE AT NMU

CANICROSS PARTICIPANT INFORMED CONSENT

I am inviting you to participate in a research study that will take place at the upcoming race you will be attending. The purpose of this study is to identify and assess the influences of several performance factors on a timed trial canicross event.

I am inviting you to this study because you are competing in the Adult Canicross- 1 dog event. One part of the study will include a one and a half mile walk/run fitness assessment, and the second part of the study will take place during your upcoming event. Approximately 20 canicross athletes will take part in this study through Northern Michigan University.

If you agree to participate, please let me know with an email response to the address given below or in person during the given event. Upon receiving your response, I will send you a brief survey to determine your eligibility to continue participation in this study. If you meet the eligibility requirements, I will contact you again to confirm when your testing of the one and a half mile walk/run will be completed via email, by phone or in person. Part one of testing will take place after the event and should not hinder the performance or the ability to race.

For part one of this study, you will be asked to complete one survey in regards to human and canine experience level upon arrival. A resting heart rate will be taken once the survey is complete and height and mass will be taken before start of the one and a half mile fitness test. Immediately following fitness assessment, rate of perceived exertion and heart rate will be tracked for a selected time thereafter. Part two of this study will take place during the race event. Measurements of human and canine mass along with human height will be taken in order to look at mass ratios between dog and human in the canicross event. During the canicross event, video cameras will be used to capture your run on both days in order to identify coordination patterns between human and canine athletes.

All data collected and any information you provide for this study will be kept confidential. However, federal regulatory agencies, Northern Michigan University Institutional Review Board (the committee responsible for reviewing and approving research studies) and thesis committee may inspect and/or copy records relating to this research. All measurements and records will be completed with an identification number to keep all records anonymous. When a report is written on the findings within the study, it will be done so individual identity can not be determined.

Since you are participating in a physical activity during this study there is a chance of injury. Risk for bodily injury include, but are not limited to, soreness and/or fatigue of the lower extremities, injuries to the muscles, ligaments, tendons and joints of the body, and a cardiovascular or respiratory event instigated by aerobic activity are all possible but not likely. Efforts will be made in order to reduce any risk of injury, such as recommending to complete a proper warm up and advising that you do not put any excessive strain on yourself during the testing procedures. An additional risk to working with and being around other domestic canines in situations such as the canicross event, is the risk brought on by the canine. Possible risks of being around this animal include, but are not limited to: cuts, scratches, bruises and puncture wounds. However, canine bites are on the most serious hazards when working with this animal. Canines can bite for many reasons but the most common reason in domestic canines would be when they are scared and/or defensive. Although very unlikely that there would be a problem, proper handling and care of the canine should be taken in any situation. This additional risk will come with the running of and/or attending any race or canicross event.

There will be no cost for the participation in this research study and no payment will be given to you. Your participation in this research study is completely voluntary and there will be no penalties, for dropping out at any time during the study. However, you will be given the opportunity after the completion of the study to see your personal and overall results of the study. The results of this study may give you a better understanding of the factors that contribute to a time trial canicross performance, along with areas of suggested improvement. You may also benefit from observational learning of how human research is performed. If the results of this study identify a critical factor of time trial performance, it would also help canicross community in understanding better training areas for future performances.

If you have any further questions regarding your rights as a participant in a research project you may contact Dr. Robert Winn of the Human Subjects Research Review Committee of Northern Michigan University (906-227-2300) rwinn@nmu.edu. Any questions you have regarding the nature of this research project will be answered by the principal researcher who can be contacted as follows: Ashlyn Jendro (320-493-4699) ajendro@nmu.edu.

I ______________________________ have read the above "Informed Consent Statement." The nature, risks, demands, and benefits of the project have been explained to me. I understand that I may ask questions and that I am free to withdraw from the project at any time without incurring ill will or negative consequences. I also understand that this informed consent document will be kept separate from the data collected in this project to maintain anonymity (confidentiality). Access to this document is restricted to the principle investigators.

☐ The canine I will be competing with is current on all rabies vaccinations.

Participant's Signature ______________________________________ Date _______________

Email Address: ____

Thank you very much for your consideration. Please return this document as indication of your willingness to participate in this research study to ajendro@nmu.edu or return to Ashlyn Jendro in person.

Sincerely,

Ashlyn Jendro
Exercise Science Graduate Student
School of Health and Human Performance
Northern Michigan University

APPENDIX B

<u>Canicross Participant Survey</u> ID #: ______________

Please complete the following survey to the best of your ability. If you have any questions or concerns regarding the survey, please contact Ashlyn Jendro.

Race: ____ Age: ____________ years

Please select class in which you will be competing in:

☐ Adult Canicross Men -- 1 dog

☐ Adult Canicross Women – 1 dog

Years Running Canicross (recreational and professional)

☐This is my first race ☐ 0-2 ☐ 2-5 ☐ 5-10 ☐ 10+

If this is not your first canicross event, what is your personal best canicross time for a 1.5-mile course and when was it (year is acceptable)?

____

Are you using your own dog? ☐ Yes ☐ No

If yes, how long have you owned the dog? ____________________________

If no, have you trained with the dog you are running before? ☐ Yes ☐ No

In preparation for this race, have you run without a dog for training or recreational purposes?
☐ Yes ☐ No

If yes, how many cumulative hours have you spent this season training WITHOUT a dog?

____

In preparation for this race, have you run with the dog you will be competing with?
☐ Yes ☐ No

If yes, how many cumulative hours have you spent this season training WITH this dog?

____

Has this dog ever run (training or competitive) in larger teams? (i.e. 4 dog rig, 6 dog sled, 2 dog scooter)
☐ Yes ☐ No

If yes, what position does the dog normally run?

☐ Lead ☐Swing / Point ☐Team ☐Wheel

Would you like to receive your results after study competition?

☐ Yes ☐ No

Thank you for completing the survey, please return survey to Ashlyn Jendro

Approved by IRB: Project # HS17-888

APPENDIX C

Application to Use Vertebrate Animals in Research, Testing or Instruction

NORTHERN MICHIGAN UNIVERSITY

Project Title (If using external funds, enter the title used on the grant application): Performance Characteristics of Adult One Dog Canicross Runners

General Instructions
Please check the IACUC website to ensure you are using the current version of the form. All parts of this form must be submitted electronically to the Institutional Animal Care and Use Committee (email: IACUC@nmu.edu) and the relevant Department Head or other departmental designee. Review of this application will commence upon receiving the electronic application, but the project may not begin until all required approval signatures are obtained via Right Signature. Please contact the IACUC chair (email: IACUCChr@nmu.edu) if you have any questions.

Review Dates:
Designated Member Review of applications (appropriate for USDA Use Categories B and C) will be completed within two weeks after receipt of the electronic application.

Full Committee Review of applications will take place on the last Friday of every month. Applications for Full Committee Review must be electronically received by the first Friday of the month. Full Committee Review is required for applications that fall under USDA Use Categories D and E. Applications that fall under USDA Use Categories B and C will receive Full Committee Review if requested by an IACUC member. Detailed procedures on the IACUC review processes are located at the IACUC website.

Shaded area for IACUC use only.

Application Number: 318
Date Application Received: October 3, 2017
☒Approved ☐ Denied on November 2, 2017.

I. **Principal Investigator** (Must be a faculty member or Department Head): Dr. Sarah Clarke

Co- Investigator: Ashlyn Jendro

Department: School of Health and Human Performance

Phone number: 320-493-4699

II. **Funding Sources/Course Information and Dates**

If the proposed work is for a course, please include the number of the course and title of the course
Thesis Credit ES 599A-02

Funding Sources (External & Internal, if applicable) Pending Charles C. Spooner Student Research Program Grant

SIGNATURE PAGE

IACUC #: **PROPOSAL TITLE (From cover page):** Performance Characteristics of Adult One Dog Canicross Runners

X. ACKNOWLEDGEMENT BY PRINCIPAL INVESTIGATOR

I acknowledge responsibility for this project. I have read the Northern Michigan University Principles for the Care and Use of Laboratory Animals and certify that this project will be conducted in compliance with those principles. I assure that I will obtain Institutional Animal Care and Use Committee approval prior to significant changes in the protocol. I assure that this project does not unnecessarily duplicate previous research or instructional projects. I assure that students, staff and faculty on the project are qualified or will be trained to conduct the project in a humane, safe, and scientific manner.

Signature: ______________________ 11/02/2017
Principal Investigator **Date**

XI. APPROVAL OF SCIENTIFIC MERIT (to be completed by the Department Head)
Before the project is initiated, it must be reviewed and approved on the basis of its scientific merit.

☐Review conducted by external agency.

☐Governmental Agency: Please specify the reviewing agency or board Federal agency (e.g., NIH, NSF, USDA, etc.) and evidence of approval

☐Nongovernmental agency (e.g., University review, specify if other):

☐Departmental Review: I assure that this project has been reviewed and approved for scientific or instructional merit by:

☐Expert reviewer (Name)

☐Departmental Committee Review (Committee Name and Chairperson):

☐Other (Describe):

Signature: ______________________ 11/02/2017
Department Head/Other Authorized Departmental Designee **Date**

XII. REVIEWED AND APPROVED BY THE IACUC

Signature: ______________________ 11/03/2017

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Revised June 19, 2014 Check the IACUC website to ensure you are using the most recent form.

Institutional Animal Care and Use Committee Chair Date

Signature: ______________________ 11/03/2017
Institutional Animal Care and Use Officer Date

Following action on this application, copies of approval or denial letters will be sent to the applicant, Department Head, and appropriate College Dean.