Kyle Bernier

Changes in the Fluidity of Coordination with Curling Experience

University of Minnesota Duluth

Abstract

This study examined the effects of experience in the sport of curling by comparing different movement tasks of curlers of varying levels of experience. We predicted that curlers with more experience would demonstrate greater amounts of flexibility in their movements, which is consistent with past studies on movement and experience (Bernstein, 1967, Vereijken, van Emmerik, Whiting, & Newell, 1992). Curlers from the Duluth Curling Club were tested on both hit and draw shots while turning their wrists in either a clockwise or counterclockwise movement. Their movement was recorded using an Optotrak Certus device which uses infrared sensors to pick up on slight differences in movement. We found that participants with more experience showed greater amounts of flexibility while performing the motion tasks. Results from this study can be used by curlers trying to make improvements to their game. Further research can be conducted to improve upon our findings.

Changes in the Fluidity of Coordination with Curling Experience

Curling is a team sport that involves sliding granite stones (also known as *rocks*) down a sheet of ice (Figure 1. Bradley, 2009) toward a target made up of four circles within one another called the *house.* The goal of the game is to slide the stones as close as possible to the center of the house while keeping the opposing team's stones away from the center of the house. An *end* is completed after each team throws eight stones. At the conclusion of an end, the winning team scores one point for each stone that is closer to the center of the house than the other team's closest stone (Bradley, 2009). Expert curlers are consistently better at throwing the stones closer to the house and knocking away opponent's stones. Little research has been conducted on the sport of curling (Lukowich, 1981). In this study, we examined the differences in the rock throwing mechanics between novice and expert curlers, where we measured different variables. Bernstein (1967) proposed that when learning a new movement skill, there is a freezing followed by a release of degrees of freedom in different joint angles of the participant. An example of a joint angle would be the composite angle between the shoulder, elbow, and wrist. As the participant practices the movement skill more, the joint angles move more fluidly (Vereijken, van Emmerik, Whiting, & Newell, 1992). Novices to a sport are overwhelmed by all the movement possibilities, so they resort to simplifying the process by "freezing out" some of those degrees of freedom, making movement more manageable. "Freezing out" can occur "by keeping the joint angles or the whole body 'rigidly, spastically fixed'" (Bernstein, 1967, p. 108), which would result in little to no joint movement. As they become more familiar with a sport, they begin to unlock their joints and create an almost singular, coordinated system.

This coordination of joint angles with experience has been observed in pistol shooting (Arutyunyan, Gurfinkel, & Mirskii, 1968, 1969), dart throwing (McDonald, van Emmerik, &

Newell, 1989), and skiing (Vereijken, et al., 1992). An example of a singular, coordinated system is the pistol shooting study. Novices keep their arm joints tightly fixed, whereas experts refrain from locking, which allows for more fluid pistol movement. In this study, reducing variability in performance resulted in better outcome measures, but as participants gained more experience, better outcome measures came not by decreasing variabilities in joint movement, but by the increase in compensatory actions of nearby joint links (Arutyunyan, et. al, 1968, 1969). In the current study, our hypothesis is that expert curlers will display better mastery and coordination of their joint angles than novice curlers by, for example, making small adjustments to throwing mechanics in real time.

A study by Yoo, Kim, and Park (2012) measured and compared the sliding motion in curlers of varying levels of experience. They measured different lower body joint angles to determine differences in technical characteristics of the sliding motion. Results of the study showed elite curlers sliding further than sub-elite curlers, on average.

Results of this study can be used by current curlers to improve their throwing mechanics or sliding motion on the ice. Curling coaches can use information from this study to make improvements to their curlers and can help even those with the most experience to make their movements more fluid. There has not been much research on curling in the past, and this is the first study to focus on differences in experience and hit/draw and in-turn/out-turn shots. Some of the questions that we had coming into the study were about which body parts would demonstrate the most variability between curlers of different experience levels, where the body started and ended up in relation to the Optotrak device, and what the differences were between hit/draw and in-turn/out-turn shots, between participants. We predicted that curlers with more experience would more accurately perform the hit/draw and in-turn/out-turn shots and would demonstrate less variability in their movements. We predicted that more experienced curlers would hold a steadier sliding motion (i.e., no fishtailing of the ankles and relatively constant hip height).

Method

Participants. Participants included 14 volunteers (four female, ten male) recruited from the Duluth Curling Club, ranging in ages 21 to 60. We were looking for participants with varying degrees of experience. Levels of expertise were broken down into years of curling with curlers with 1-3 years of curling experience put into the 'novice' category and curlers with 4+ years put into the 'expert' category. For this study, curling experience ranged from one year of curling practice to 22 years of curling practice. Potential participants were excluded if they were under the age of 18, had a physical disability that could become aggravated by curling or impair their movements, were under the influence of alcohol, or did not have enough experience with the sport. Participants completed a brief questionnaire gauging their perceived level of experience. Participants were compensated with a $10 gift certificate to UMD Stores.

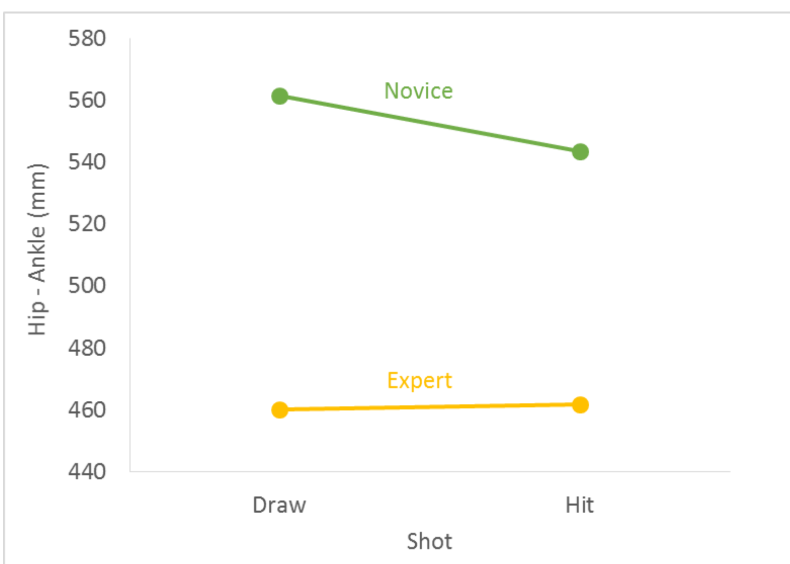
Materials and Apparatus. We created an expertise survey to gauge our participants' past curling experience. This form was filled out, with our supervision, prior to performing the trials. The expertise survey gathered information on what age the participant started curling, when they started deliberate practice to improve their game, and when they began competing in curling competitions. We also asked about the level the competitions were at (i.e., club, regional, national, international), and how many they have attended. Participants filled in how many hours per week in the past five years they practiced curling deliberately, and any injuries they received during that time. Finally, participants listed any past sports they competitively took part in the past or currently, in addition to curling. An Optotrak Certus motion tracking device (Northern Digital, Waterloo, Canada), was used to record movement in real time. Infrared emitters were secured to the right side of each participant's body. Emitters were placed on the shoulder, elbow, and wrist of the arm. Additionally, they were placed on the hip, knee, and ankle of the leg. Movement was sampled at 60 Hz. For this study, we used the same curling rock for each of the trials, for each participant. We used curling sheet eight for every trial, which was maintained to tournament standards.

Procedure. After initial contact, participants met us down at curling sheet eight, where they gave informed consent, filled out the experience survey, demographics form, and PAR Q form, which gauged their current physical condition. Participants were excluded from the study if they were under the age of 18, had any physical disabilities that could affect their curling abilities or be worsened by performing said activities, or were under the influence of alcohol. Participants were then hooked up to our motion tracking equipment on the right side of their body. Once hooked up to the equipment, participants were asked to take a practice shot using the designated rock which was used for each practice shot and experimental trial. Next, participants were asked to perform two different throws (which were counterbalanced across participants); one in-turn and one out-turn, while we noted how close the stone was to the center of the house. An in-turn throw involves rotating the handle of a stone across the body (for a right-hander, turning the stone clockwise) and an out-turn throw, rotating the handle of a stone away from the body (for a right-hander, turning the stone counter-clockwise). Participants then performed eight trials consisting of four draw shots (2 in-turn, 2 out-turn) and four hit shots (2 in-turn, 2 out-turn). A draw shot is a shot that lands without hitting another stone. A hit shot is a shot that is meant to hit an opponent's stone out of the house. As participants were performing their throws, we recorded whether or not they successfully completed the assigned throwing method (i.e., draw/hit, in-turn/out-turn) using a shot performance sheet. We recorded whether or not the participant was able to successfully slide the stone into the *house* for draw shots and whether or not they were able to hit the stationary stone, which was planted in the same spot in the *house* for hit shots. This method of recording accuracy was similar to Harrington's experimental study of the motion of curling stones (1924). The motion tracking and data recording software were loaded on the computer prior to each participant arriving for the study. The duration of each experimental session was about 15 minutes. If participants' throws did not make it past the hog line, they were asked to repeat that specific trial. Immediately after each experimental session, participants were debriefed, given compensation, and dismissed.

Results

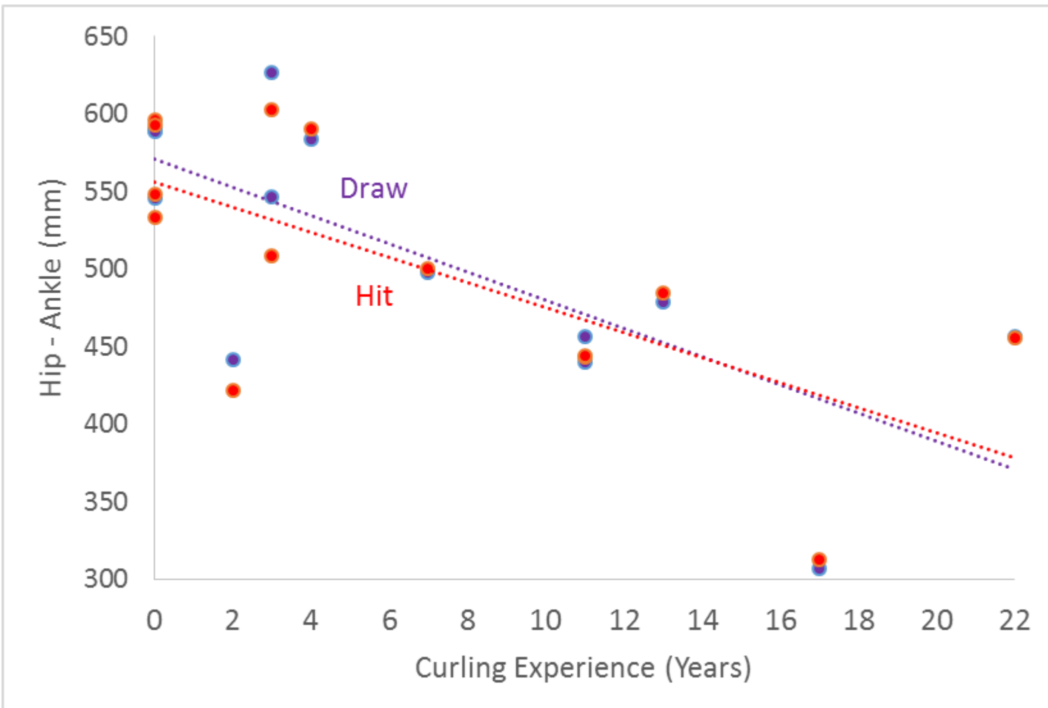
Study participants were given one practice throw to warm-up before beginning the experimental trials. Trials where participants were unable to throw the rock beyond the hog line (the line before the house) were eliminated from the study and were re-run. We measured the hip to ankle variable in participants and found that experts lowered their hips in relation to their ankles further than novices for both hit and draw shots.

Figure 1.



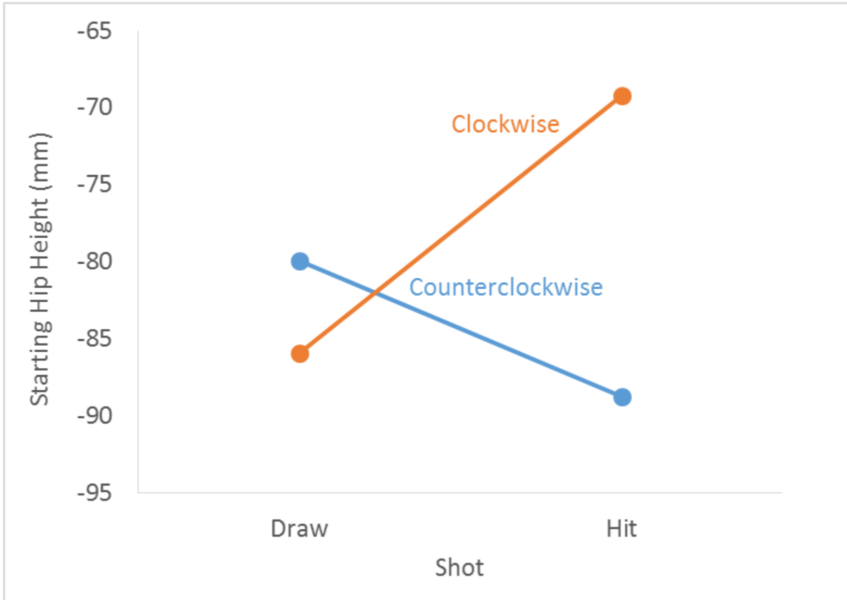
However, novices lowered their hips in relation to their ankles more on hit shots rather than draw shots. The shot x expertise interaction was $F(1, 12) = 4.40$, $p = .058$ (Figure 1). There was a main effect of expertise which was $F(1,12) = 5.56$, $p < .05$ (see figure 2). Experts' hip to ankle ratio was, on average, 460.83 mm high and novice's hip to ankle ratio was 552.43 mm.

Figure 2.



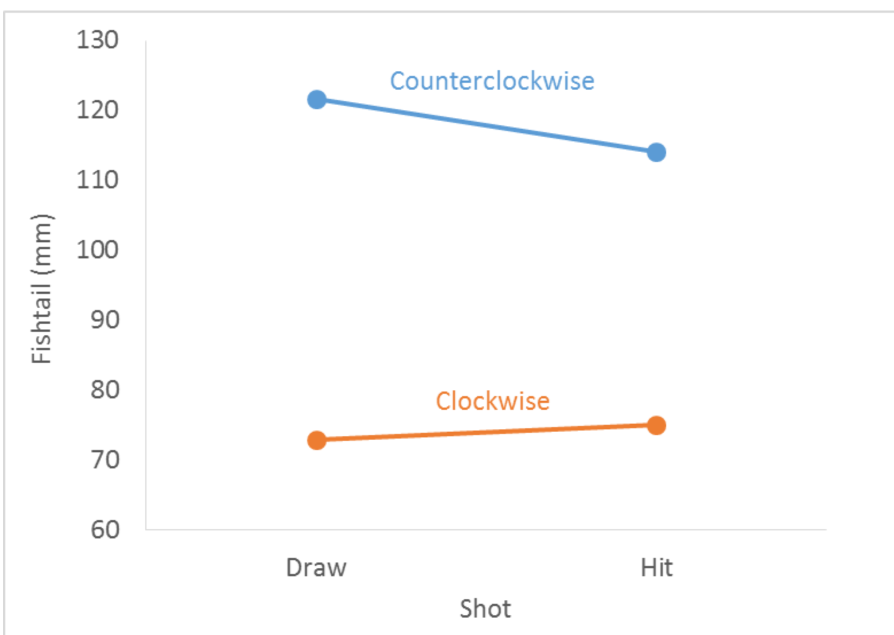
We measured the variable starting hip height for both hit and draw shots and whether they were clockwise or counter-clockwise. We found that there was no difference in starting hip height for clockwise and counter-clockwise draw shots but there was a difference in starting hip height for clockwise and counter-clockwise hit shots. Starting hip height is higher for counter-clockwise hit shots than it is for clockwise hit shots. The shot and turn interaction was $F(1,12) = 5.27$, $p < .05$ (see Figure 3).

Figure 3.



We predicted that novice participants would demonstrate a higher amount of fish-tailing, where the ankle moves further away and closer in relation to the Optotrak Certus device. We measured the ankle's location at one point in time and then one second later to capture how far it had deviated from the start time to end time. Our data indicated a significant main effect of turn

Figure 4.



of $F(1, 12) = 18.37$, $p < .01$ (see Figure 4). This indicates that there was more fishtailing for counter-clockwise throws than clockwise throws between both novice and expert curlers.

Discussion

The purpose of this study was to test the differences in expertise on different curling movements. We predicted that curlers with more experience would demonstrate more fluidity in their movements and less variability in hip and ankle locations. We predicted that more experienced curlers would demonstrate a lower hip to ankle ratio for all types of shots. Our results indicated that experts did have a smaller hip to ankle ratio than novices but we did not account for the different types of turn within the shots for novices. Experts remained consistent between hit and draw shots in terms of their hip to ankle ration, but novices showed some variability between shot types, showing a smaller hip to ankle ratio for hit shots only. Thus, our hypothesis was partially supported, with the main effect of expertise showing support. But, we did not account for the interaction effect of shot type and expertise level.

The findings of this study indicated that there was an interaction effect between shot and turn type, where there was a difference in starting hip height for in-turn (clockwise) and out-turn (counter-clockwise) turn types in hit shots. Starting hip height was higher for counter-clockwise turn hit shots than it was for clockwise turn hit shots. However, for draw shots, it did not matter which type of turn was used. We predicted that curlers with more experience would demonstrate a lower amount of fish-tailing than their novice counterparts, meaning that more expert curlers would keep their body more inline throughout the sliding motion. Their ankle would stay in relatively the same position throughout the trial. Our study indicated that there was a main effect of turn type where there was more fishtailing for counter-clockwise turns than clockwise turns.

Future directions for further research could use speed as a potential variable, measuring whether or not more expert curlers pushed out of the hack (the block-like kickoff point at the beginning of the sheet) quicker than more novice curlers, or whether they sustained that speed better than novice curlers. Future studies could measure at what speed, on average, curlers started out of the hack at and what they ended at by the time they released their stone. In order to figure out that variable, you would need consistent data, devoid of any gaps. In our current study, we have small gaps in our data where both markers were not picked up by the Optotrak. A study by Kivi and Auld (2010) measured the relative speed of several different curling shots between "competitive" and "recreational" curlers performing a number of different shot and turn types. Their results showed that average speeds for curlers of different expertise levels varied depending on shot/turn type. Another direction this type of research could be taken is the ankle between the wrist, hip, and ankle. This would allow us to see how in-line the curler is throughout their sliding motion. We predict that curlers with more experience would have less variability and the three joints would create a near 180 degree angle. In future studies, we could also measure different joint angles between different joints (i.e., wrist, elbow, and hip or ankle, knee, and hip) and make comparisons between novice and expert curlers. For this study, we only placed markers on the right side of our participant's bodies. In future studies, markers could be placed on participants' left side, which would allow us to record their sliding foot and left hand which is placed on the broom while sliding. More research could be done from the participant's posterior side, where square-ness of shoulders can be measured in relation to the participant's hips.

In conclusion, results of this study provide some fascinating insights into the biomechanical differences between curlers of different experience levels and can be used to develop a better long-term technique in curlers still learning the game and more experienced curlers who are looking to make improvements to their already existing game. This research has shown some of the advantages to using certain turn types during certain shot types. Coaches can use the results of the study to create more specific techniques for increasing fluidity. With the small amount of research previously and currently being conducted, the results of this study suggest that we have much to learn about different curling mechanisms that differences in expertise has shown us.

References

Arutyunyan, G. H., Gurfinkel, V. S., & Mirskii, M. L. (1968). Investigation of aiming at a target. *Biophysics, 13,* 536-538.

Arutyunyan, G. H., Gurfinkel, V. S., & Mirskii, M. L. (1969). Organization of movements on execution by man of an exact postural task. *Biophysics, 14*, 1162-1167.

Bernstein, N. (1967). *The coordination and regulation of movements.* New York: Pergamon Press.

Bradley, J. L. (2009). The sports science of curling: A practical review. *Journal of Sports Science & Medicine*, *8*(4), 495-500.

Harrington, E. (1924). An experimental study of the motion of curling stones.*248-259*.

Kivi, D., & Auld, T. (2010). Temporal methods to estimate the displacement of a curling rock: Comparison between competitive and recreational curlers. *International Symposium On Biomechanics In Sports: Conference Proceedings Archive*, *28*1-284.

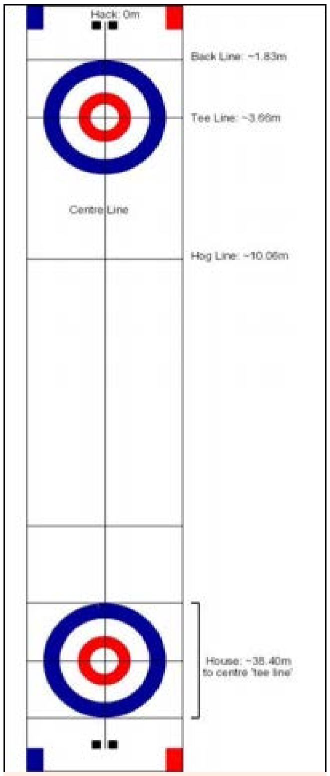
Lukowich, E., Folk, R., Gowsell, P. (1981*).* The curling book. *Modern Press.*

Verijken, B., van Emmerik, R., Whiting, H. T. A., & Newell, K. (1992). Free(z)ing degrees of freedom in skill acquisition. *Journal of Motor Behavior, 24, 133-142.*

Yoo, K., Kim, H., Park, J. (2012). A biomechanical assessment of the sliding motion of curling delivery in elite and subelite curlers. *Journal of Applied Biomechanics. 28, 694-700.*

Appendix

Figure 4.



Optotrak Certus (Northern Digital, Waterloo, Canada) (see Figure 5)

Copied are the sections of the Optotrak Certus User Guide that are relevant to the emitters (referred to as Smart Markers in the guide) and associated technology that was used to record movement. Section 1.1, Basic System Components, provides names and descriptions of the basic components of the Optotrak Certus system. Chapter 11, Smart Markers, provides detailed information about smart markers and methods that can be used to collect movement data.

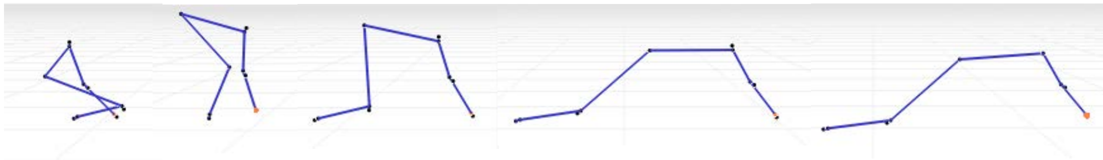
On page 65, the smart marker is defined as “an infrared light emitting diode (IRED) housed in an enclosure…When activated, the smart marker emits infrared light”. That is, a smart marker is similar to LEDs that are used in many electronic applications, except that they emit light that is in the infrared spectrum as opposed to in the visual spectrum. Light in the infrared spectrum is a longer wavelength form of energy than light in the visual spectrum.

Smart markers (emitters) were attached to elastic Velcro straps which were then worn by the participant. The markers will be tethered together in a chain with smart marker interconnect cables and then connected to a wireless strober. The interconnect cables are flat and virtually tangle-free (page 65, Optotrak Certus User Guide). They were loose enough to allow the participant to move freely but not so loose that they would be a tripping hazard. Data was collected in the wireless mode (page 65-66, Figure 11-2). Signals to turn on the smart markers were transmitted to a battery powered wireless strober via a wireless transmitter. The battery pack and wireless strober were attached around the participant's waist. The wireless mode of data collection allowed the participant greater freedom of movement (page 65) than using the alternate wired mode and did not inhibit participants' movements or increase their risk of accidents or injuries. In the wireless mode, there is no cable connecting the participant's body with the data collection computer.

Figure 5.

Sample Optotrak Movement Progression Chart

Figure 6.



Experience Survey

Participant Code:________________

1. At what age did you start to participate in each of the following activities?

-Curling: _______ years

-Deliberate practice activities designed to improve your curling ability: _______ years

-Competitive matches against another curler or team of curlers: _______ years

2. What is the highest level of curling competition that you have reached?

☐ club ☐ regional ☐ national ☐ international

3. Prior to today, how many of the following events have you competed in?

_______ national events _______ international events

a) Of those events, how many did you finish in the top three teams?

_______ national events _______ international events

4. Which of the following events have you curled in? *(complete all that apply)*

☐ National championship ☐ World championship ☐ Olympic games

5. In each of the following curling seasons, during a typical week:

a) How many hours did you participate in deliberate practice designed to improve your curling ability?

2014-2015 season: _______ hours/week

2013-2014 season: _______ hours/week

2012-2013 season: _______ hours/week

2011-2012 season: _______ hours/week

b) How many competitive matches did you participate in against another curler or team of curlers?

2014-2015 season: _______ matches/week

2013-2014 season: _______ matches/week

2012-2013 season: _______ matches/week

2011-2012 season: _______ matches/week

6. In any of the following curling seasons, did you miss a substantial part of the season due to injury?

☐ 2014-2015 season injury/injuries sustained: ______________________________

☐ 2013-2014 season injury/injuries sustained: ______________________________

☐ 2012-2013 season injury/injuries sustained: ______________________________

☐ 2011-2012 season injury/injuries sustained: ______________________________

☐ 2010-2011 season or before injury/injuries sustained: ______________________________

☐ No injury/injuries in any of the seasons above

7. In any of the following curling seasons, did you miss a substantial part of the season because you were taking a break from curling (not injury related)?

☐ 2014-2015 season reason for break: ___________________________________

☐ 2013-2014 season reason for break: ___________________________________

☐ 2012-2013 season reason for break: ___________________________________

☐ 2011-2012 season reason for break: ___________________________________

☐ 2010-2011 season or before reason for break: ___________________________________

☐ No breaks from curling in any of the seasons above

8. In your estimation, did your curling ability peak in one of these curling seasons?

☐ 2014-2015 season

☐ 2013-2014 season

☐ 2012-2013 season

☐ 2011-2012 season

☐ 2010-2011 season or before

☐ I have not reached my peak level of curling ability *(skip to item 11 below)*

9. At what age did your curling ability peak? _______ years

10. In the curling season that your curling ability peaked, during a typical week:

a) How many hours did you participate in deliberate practice designed to improve your curling ability? _____ hours/week

b) How many competitive matches did you participate in against another curler or team of curlers? _____ matches/week

11. As a child and/or adolescent, list all of the sports in which you were an active participant?

______________________ ______________________ ______________________

______________________ ______________________ ______________________

______________________ ______________________ ______________________

12. If you specialized in curling over other sports that you participated in as a child or adolescent, at what age did you specialize in curling?

_____ years

Physical Activity Readiness Questionnaire (PAR Q)

Changes in the Fluidity of Coordination with Curling Experience

PARTICIPANT CODE:______________ HEIGHT:____________in.

WEIGHT: ___________lbs.

Questions	Yes	No
Has your doctor ever said that you have a heart condition and that you should only perform physical activity recommended by a doctor?		
Do you feel pain in your chest when you perform physical activity?		
In the past month, have you had chest pain when you were not performing any physical activity?		
Do you lose your balance because of dizziness or do you ever lose consciousness?		
Do you have a bone or joint problem that could be made worse by change in your physical activity?		
Is your doctor prescribing any medication for your blood pressure or for a heart condition?		
Do you know of <u>any</u> other reason why you should not engage in physical activity?		

If you answered "Yes" to one or more of the above questions, consult your physician <u>before</u> engaging in physical activity. Tell your physician which questions you answered "Yes" to. After a medical evaluation, seek advice from your physician on what type of activity is suitable for your current condition.