TOJRAS The Online Journal of Recreation and Sports 12(3), 2023
ISSN: 2146-9598 Review

# From Past to Present The Most Mysterious Olympic Sport: A Review of Curling Sport

*Geçmişten Günümüze En Gizemli Olimpik Spor: Curling Sporu Hakında Derleme*

*Fatih Ağduman[1], Deniz Bedir[2]

[1]Atatürk University, Faculty of Sport Sciences, Erzurum, TÜRKİYE / f.agduman@atauni.edu.tr / 0000-0002-5744-7191
[2]Erzurum Technical University, Faculty of Sport Sciences, Erzurum, TÜRKİYE / deniz.bedir@erzurum.edu.tr / 0000-0002-5926-3433
* Corresponding author

**Abstract**: The popularity of curling, a target sport played on ice with rocks, has been steadily increasing. The number of World Curling Federation member countries has doubled in the last two decades. Shortly after taking part in the Olympics in 1998, curling became one of the most popular winter sports on TV. The reflections of the interest in the society have found a response in the world of science and an increase has been observed in the number of scientific studies on curling. However, despite the increase in studies, there is currently no comprehensive literature review that provides fundamental information about the sport of curling. The aim of this review is to provide general information about the sport of curling and its rules by filling the gap in the literature examining the scientific studies in this field. In this review the history, organization management, rules, strategy, ice properties, materials used and scientific research on the sport of curling are mentioned. While previous studies, particularly in the field of engineering, have explored aspects such as the structure of ice, sweeping techniques, and the movement of stones on ice, many mysteries still remain to be unrevealed..

**Keywords:** Olympic Games, chess on the ice, sweeping, target sport, winter sports.

***Özet:*** *Beş yüz yıldan uzun bir süredir buz üzerinde taşlarla oynanan ve buzun satrancı olarak adlandırılan curling sporunun popülaritesi her geçen gün artmaktadır. Curling sporuna olan ilginin artmasının en önemli göstergelerinden biri de Dünya Curling Federasyonu üye ülke sayısının son yirmi yılda iki katına çıkmasıdır. Curling branşı 1998 yılında olimpiyatlara dâhil edildikten kısa bir süre sonra televizyonlarda en çok izlenen kış sporlarından biri haline gelmiştir. Toplumsal ilginin yansımaları bilim dünyasında da karşılık bulmuş ve curling ile ilgili bilimsel çalışmaların sayısında artış gözlemlenmiştir. Ancak çalışmalardaki artışa rağmen şu anda spor hakkında temel bilgiler sağlayan kapsamlı bir literatür taraması bulunmamaktadır. Bu derlemenin amacı, bu alandaki bilimsel çalışmaların incelenerek literatüre katkı sunmak, curling sporu ve kuralları hakkında genel bilgi vermektir. Bu derlemede curling sporunun tarihçesi, organizasyon yönetimi, kuralları, stratejisi, buz özellikleri, kullanılan malzemeler ve bilimsel araştırmalara değinilmiştir. Daha önceki çalışmalar, özellikle mühendislik alanında, buzun yapısı, süpürme teknikleri ve buz üzerinde taşların hareketi gibi yönleri araştırmış olsa da, curling branşıyla ilgili hala çözülmeyi bekleyen birçok gizemli nokta bulunmaktadır.*

***Anahtar Kelimeler: Olimpiyat Oyunları, buzun satrancı, süpürme, hedef sporu, kış sporları.***

Received: 25.05.2023 / Accepted: 12.06.2023 / Published: 30.07.2023

https://doi.org/10.22282/tojras.1302666

***Citation:*** *Ağduman, F., & Bedir, D. (2023).* From past to present the most mysterious olympic sport: a review of curling sport, *The Online Journal of Recreation and Sports (TOJRAS), 12(3), 314-325.*

## INTRODUCTION

Played by more than 2 million people of all ages in 70 countries, curling attracts more attention with the inclusion of the mixed doubles category in the Olympics. Curling, which was first played in Scotland in the 16th century, is today most popular in Canada. According to the text on the spirit of curling on the first page of the World Curling Federation (WCF) rulebook in the sport where the concept of fair play is extremely important, "a curling player would rather lose than win the match unfairly" (Federation, 2020a).

Many countries with no previous curling background or experience have launched national curling programs in hopes of sending teams to the Olympics. Curling is one of the most watched activities of the Olympic games, especially on television (Turriff, 2016). With world-famous companies sponsoring various championships, curling reaches larger masses and attracts more people. In the sport of curling, which has become increasingly popular, award-winning tournaments called cashspiel (Weeks, 2020) are organized, as in tennis and other sports.

One of the features that distinguishes curling from other sports is that it can appeal to people of all ages. Especially since skips do not make much effort physiologically, they can play curling at elite level for many years. Experience can make a difference in competitions as it is an extremely important factor. Looking at the successful teams, it is striking that the teams formed by the athletes who play together for a long time are more successful.

**Table 1.** Some olympic / world champion skips & ages (federation, 2020b)

| Event | Year | Name | Age |
|---|---|---|---|
| Winter Olympic Games (Men) | 2002 | Pal Trulsen (NOR) | 40 |
| Winter Olympic Games (Men) | 2006 | Russ Howard (CAN) | 50 |
| Winter Olympic Games (Men) | 2010 | Kevin Martin (CAN) | 44 |
| Winter Olympic Games (Women) | 2010 | Anette Norberg (SWE) | 44 |
| World Curling Championship (Men) | 2012 | Glenn Howard (CAN) | 50 |
| World Curling Championship (Women) | 2010 | Andrea Schöpp (GER) | 45 |
| World Curling Championship (Women) | 2018 | Jennifer Jones (CAN) | 44 |

Studies on sport of curling are related to curling stone (Bradley, 2009; Denny, 2002; Haggerty, 2013; Jensen & Shegelski, 2004; Lozowski et al., 2015; Marmo & Blackford, 2004; Nyberg et al., 2013; Penner, 2001), sweeping (Bradley, 2009; Buckingham et al., 2006), engineering (Shegelski & Lozowski, 2019), physiology (Schmid et al., 2016), history of curling (Mair, 2007; Mott & Allardyce, 1989) and psychological factors (Collins & Durand-Bush, 2010, 2014; Lizmore et al., 2016; Stewart & Hall, 2016; Stewart et al., 2016). Although there have been researches on many different subjects related to sport of curling, there is no study that explains curling in all its dimensions and emphasizes the important points. In this study, it is aimed to provide more detailed information about curling by compiling previous

researches. It is believed that researcher would have more comprehensive source about sport of curling by this review.

### *History*

Curling is an ice sport in which two teams each throw eight granite stones at a target, or "house" (Bradley, 2009). It is a winter team sport which is described as a combination of bowling and chess (Kostuk et al., 2001). According to the records, curling was first played in Scotland in the 16th century (Curling, 2020). Curling, a target sport where people played with stones on frozen lakes, developed more in Canada with the Scots who immigrated to Canada in the 18th and 19th centuries (Mott & Allardyce, 1989). The game with the status of medal sport in the first modern winter Olympics in Chamonix in 1924, it took part as a demonstration sport in the 1932, 1988 and 1992 Olympics and later regained the status of medal sport in 1998 Nagano and was included in the program in all subsequent Olympics (Mair, 2007). Curling, played in the men's only category in 1924 Chamonix, took place in 1998 Nagano as a medal sport for both men and women. After the wheelchair discipline (Giovanis & Margari, 2015), which was added to the 2006 Torino Paralympic Winter Games, the mixed doubles category, which is a new discipline, at the 2018 Pyeong Chang Olympics, also gained the status of medal sport.

Today, all official organizations related to the sport of curling are run by the WCF. Founded in 1966 as the International Curling Federation (ICF), it was then named the World Curling Federation in 1991. While there were 30 member countries affiliated to WCF in 1998, this number was 64 as of 2020. In international official organizations, junior (under age of 21), senior (above age of 50) and mixed (2 men - 2 women) world championships are organized in addition to the disciplines of women, men and mixed doubles. World championships have been organized annually since 1959 for men and 1979 for women (Wieting & Lamoureux, 2019). Canada remains by far the most successful country in both categories (36 gold medals for men, 17 gold medals for women) (Wikipedia, 2020). According to the report published by the Coaching Association of Canada, 1.986.000 people in Canada played curling at least once in 2019 (Curling Canada, 2020).

### *Game of curling*

Curling is the only sport in which the trajectory of the projectile can be influenced after it has been released by the athlete among target sports (Buckingham et al., 2006). It is a team sport formed by four people aiming to place curling stones as close as possible to the center of the target called the house (Bradley, 2009; Steele et al., 2014). In the game called chess on ice (Haggerty, 2013), along with physical characteristics such as balance, coordination, strength and endurance (Auld & Kivi, 2010), psychological features such as mental training (Hansen, 1999), self-talk (Pezer, 2007), communication (Jones, 2007;Weeks, 2020), strategy (Weeks, 2020) and analytical thinking (Pezer, 2007) are also extremely important. During a curling game, it is strictly forbidden for the coach to communicate verbally or non-verbally with athletes. During the 10-end curling game, the coaches can only communicate with the athletes for 5 minutes after the 5th end and 1 minute during the time out that can be taken by the athletes, so the players must have enough knowledge of the game to win the game without tactical support from the coach. Since the concept of fair-play is extremely important in the game, the influence of the umpire is negligible. In accordance with the spirit of curling, when athletes violate the rules, they report this to the opposing team and the decision is usually made by the opponent. At the point where the players of both teams disagree, the umpires step in and make the final decision.

Sport of curling getting more attractive in the World but the biggest problem for people is access of the curling facilities and equipment as it is very expensive to build a curling rink. To solve this problem, make the sport of curling more accessible and attractive for future generations floor curling branch has emerged and supported by World Curling Federation and other national curling federations.

### *Ice*

Curling ice requires special procedures because it is different from ice hockey or figure skating in terms of its structure and intended use. Just before the game, ice technicians throw water droplets called pebbles (see image 1) (Jensen & Shegelski, 2004) of different sizes and patterns on the ice according to the condition of the field, and the field of play called sheet scraped with machines is made ready for the competition. The water heated up to 60 C is sprinkled on the sheet by the ice technician using different size of pebble heads (Braghin et al., 2016). The player slides together with the stone weighing about 20 kg (Willoughby & Kostuk, 2004) by means of the handle, rotating the stone with his hand to turn it left or right. Since the pebble sizes are different and do not distribute uniformly on the field, the stone may not always curl the same way in all areas of the ice. Since the pebble heads are not broken at the beginning of the game, the stones thrown go slower due to excessive friction. Towards the mid ends of the game, the stones break the pebble heads and go faster as they rub against the ice less. Last sections of the game the stone starts to slow again as the pebble is almost completely destroyed and the friction increases (see figure 1) (Howard, 2010). Sometimes ice technicians knip the pebbles with a blade just before the game. This is done to to achieve optimum level playing conditions more quickly. If this is not done the ice will take upwards of three ends before attaining desired conditions. One of the most important factors in the game is to be able to "read the ice" in order to predict in which part of the field the stones played will go faster / slower or curl / straight. The friction will increase as the pebble melts and the field becomes flat in the area of the ice that is swept too much, so the stone will go slower and the curl will

increase.

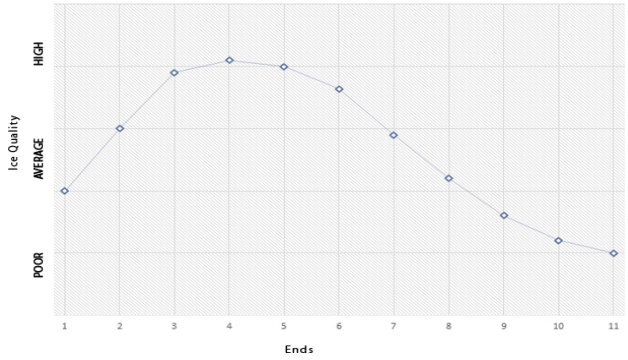


**Figure 1.** Ice quality/playing conditions according to ends considering pebbles were not knipped before the game.

In order to better understand these factors, both teams are given a 9-minute "ice recognition" time called pre game practice just before the game. During the pre game practice, athletes throw stones to understand how the stones react on ice and to read ice (In which area the stones go faster, in which areas get more curl or go straight etc.). It will be easier for the team that can read ice better to outperform their opponent because they know which part of the field and with which speed and curl to throw stones. Thanks to the sweeping, which seems extremely strange to people unfamiliar with the game, the ice is heated by sweeping the path in front of the stone. The stone goes farther as the sweeping produces friction heat between the broom head and the ice, bringing the temperature of the ice closer to its melting point and reducing the friction coefficient (Marmo et al., 2006). In addition, athletes can sweep the path in front of the stone in different ways so that the stone curls more or less.

**Image 1.** Icemaker pebbling the ice surface (Hendry, 2014).

***Ends and players***

A curling game consists of 10 parts, each called "end", and lasts approximately 2.5 - 3 hours. The team that gets more points than its opponent at the end of 10 ends wins the game. At the conclusion of 10 end, if the teams do not get an advantage over each other, an extra end will be played. The team that breaks the tie in the extra end wins the game. Considering that 14 games must be played in order to win a medal in the Olympics or World Championships, it can be said that the sport that requires the longest time to get a medal during the championship is curling with 35 hours of performance (Bradley, 2009). Winning the game by lots of points in curling doesn't make any difference, so there is no average system. That's why athletes focus only on winning the game, rather than winning by many points. This situation requires athletes to think more strategically. The two teams throw 8 stones each towards the target called the house with sequential moves (as in chess) during each end, and the points obtained by scoring according to the proximity of the stones to the center of the house at the conclusion of the end are shown on the scoreboard. Since each team throws 8 stones in one end, a total of 10 * 8 = 80 stones are thrown per team during the game. If the gap in points reaches a level that cannot be closed mathematically during the game or a team believes that they will not win, they may withdraw from the game without throwing the remaining stones by shaking opponent team athletes' hands. In this case, the score at the moment the defeated team withdraws from the game by accepting the defeat is registered. In a game where all stones are played, a total of 160 stones are thrown, 80 of which is Team A and 80 for Team B. The thinking time given to each team to throw 80 stones is 38 minutes. Thinking time refers to the time remaining outside of the time the stones travel on the ice. In this time, the players decide how to place the stones. Although it varies for each shot type, the average time a stone travels on ice is 20-25 seconds. The duration of the curling game can be up to 2.5 - 3 hours, with time-outs taken in the game, a 5-minute break at the end of the 5th end, and extra end. If a team fails to throw 80 stone within the 38 minute thinking time, they will be forfeited to be defeated regardless of the score (Federation, 2020a). Therefore, it is extremely important to make decisions by thinking quickly and correctly, as well as tactics and strategy (Otani et al., 2016).

Since the teams consist of 4 athletes, all players make 8 moves belonging to their teams by throwing 2 stones at each end in the order determined by the coach before the game. In this case, each player must have a fixed throwing order. Provided that each end is thrown in the same order, leads throw 1. and 2., seconds throw 3. and 4., thirds throw 5. and 6., and fourth players throw 7. and 8. stones to the house (Tamminen & Crocker, 2013).

**Table 2.** The order of delivery and sweeping (In case of 4th player is skip, 3rd player is vice) (Weeks, 2020)

| Stone order | Delivering athlete | Sweepers |
|---|---|---|
| 1. and 2. | Lead | Second and third |
| 3. and 4. | Second | Lead and third |
| 5. and 6. | Third | Lead and second |
| 7. and 8. | Fourth | Lead and second |

As one player throws a stone, two teammates follow the stone to sweep, while the other athlete directs the game at the other end of the sheet (Collins & Durand-Bush, 2019). This athlete, called the skip, gives instructions on where / how the athletes throw the stone and when / how the sweepers should sweep.

When it is the skip's turn to throw, the vice-skip moves to house and directs the game.

The skip and vice-skip sweep less stones than other athletes as they are more responsible for tasks such as directing the game and strategy and must not leave the house. The skip or vice-skip can be any player in the team, but 4th players are generally preferred as the skip. The reason for this may be that the 4th players can think more calmly, cool and rationally under pressure than other players. In addition, the athletes who have the most game / position knowledge in the team are skips. Since the intervention of the coaches in the game is limited, the skips usually decide how to play the moves. Other players regarding the current position can also give their opinions to the skip at any time, or the skip can ask for the opinions of teammates at any time.

### *Field of play*

The curling game is played on a 45.72 m long 5 m wide field called sheet. The athlete, whose turn to throw, after positioning his/her foot on one of the spots called hack, slides with the stone and throws the stone towards the house on the other side of the sheet. The shapes obtained when the sheet is divided horizontally in the middle are symmetrical to each other. This is because it allows the game to be played from both sides. Since the stones thrown at the conclusion of the first end accumulate on the other side of the sheet, the athletes can start the game without moving the stones back when starting the second end. In this way, players make five round trips in a game and 10 ends are completed. When throwing, players must release the stone before the first hog line (violation line). If the athlete slid with the stone and came to the first hog line with contact with the stone, the stone is taken out of the game. Whether the players commit hog line violations is checked with the help of the hog line umpires or electronic system technology placed on the ice floor and stones. Players can slide as far as they want after releasing the stone but they must not damage the ice. Since the ice is sensitive curling athletes attach great importance to the ice surface. The game can be lost, as even a strand of hair falling on the ice surface can affect the curl and route of the stone. That's why there are warnings in the rulebook that athletes should be sensitive to ice (Federation, 2020a).

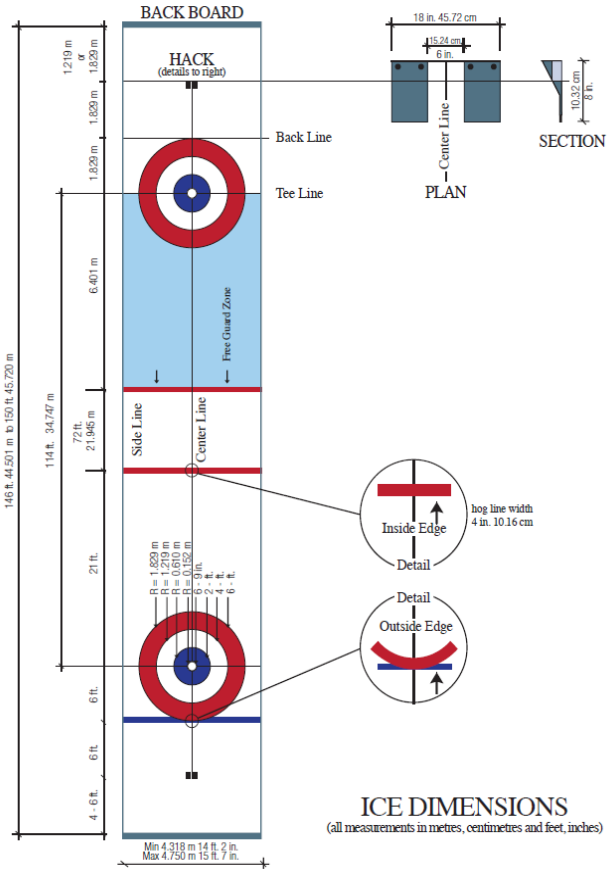


***Figure 2.*** Sheet dimensions (Federation, 2020a)

In order for the stone to be accepted on the playing field, it must pass the second hog line. Any stones that do not cross this line are taken out of play (Federation, 2020a). The line called T line divides the house horizontally in half. Stones can be swept away from the center by the opposing team after crossing the T line and - if any - get their own stones closer to the center of the house to score points. The back line is the last line where the stones can stay in the game (Howard, 2010). Stones that completely cross the back line are considered out of play. From these expressions, it can be concluded that the stones must remain between the hog line and the back line in order to be accepted in the game. The center line is the line that divides the sheet vertically from the middle into two equal parts. Thanks to the center line, skips can tell players to sweep by seeing how far the stone moves from the center or approaches the center when the stone is curling. Therefore, the center line is generally regarded as a reference line for players on curling stones. There are houses with a diameter of 3.66 meters consisting of intertwined rings at both ends of the sheet. The four intertwined circles are called the 12-foot, eight-foot, four-foot circle, and button, respectively (Weeks, 2020). Contrary to popular belief, having different colors of the circles does not necessarily mean getting more points. The reason why the circles are different colors is to allow athletes to decide more easily and quickly which team's stone is closer to the center of the house during the game.

***Equipment***

***a) Stones***

With the first emergence of the game, curling stones did not have a standard shape and have changed their form with the modernization of the game. Today, circular shaped curling stones are made from a very unique form of granite, only extracted from Ailsa Craig, a tiny island off the coast of Scotland. The granite in Ailsa Craig is the only rock suitable for producing curling stones, aside from a small vein found in Wales (Turriff, 2016). A curling stone weighs about 20 kg. with its handle (Federation, 2020a). The base of the stone is concave. Its circumference is approximately 92 cm and its height is approximately 12 cm (Braghin et al., 2016). Thanks to the handles, athletes can rotate the stone by turning it to the right or left.

**Image 2.** The first curling stones (Kerr, 1890)

**Image 3.** Modern curling stones

***b) Shoes***

Due to special ice requirements in curling, athletes wear special shoes. In order for the athletes to throw the stones by sliding, although it varies according to the dominant hand, one of the soles of the right or left foot is covered with teflon or steel called slider. The material on the other foot, which is made of rubber and ensures that they do not slip on ice, is called a gripper. While newcomers to the sport of curling generally prefer sliders with thinner soles. Athletes who can slide more balanced use curling shoes with higher teflon thickness and therefore can slide faster. Due to the throwing position, the left foot sole of the athletes who throw stones with their right hand is made of teflon / steel material. The exact opposite is the case for athletes throwing with the left hand.

**Image 4.** Shoes

**Image 5.** Slider

**Image 6.** Gripper

***c) Broom/Brush***

The brooms used in curling throughout history are made of different materials. The handle of the broom was first produced from heavy materials such as wood then lighter materials were used for the athletes to spend less energy during sweeping. While broom heads made of corn tassel were used in the 1950s later brush-like brooms were produced. Undoubtedly, since the most important part of the broom is the part that touches the ice, different fabrics produced with technological developments show very different results in terms of heating the ice. The WCF has made it mandatory to use only one type of fabric as a broom head. This prevented a team from gaining an advantage over its opponent due to the different broom heads used.

**Image 7.** Corn broom (Janik, 2010)

**Image 8.** Hair broom (Grassie, 2017


**Image 9.** Cloth – covered broom

***Scoring***

What should be done to get points in the game; At the conclusion of the end (when 16 stone have been delivered), it is to count as many stones as possible closer to the center of the house than the opponent's stone nearest to the center of the house. The first condition to get a point is that the stone has to touch the house at the conclusion of the end. Stones that do not touch the house cannot be entered in the scoreboard. Both teams cannot score points at the same end.

So the end cannot result in scores such as 2 - 1, 3 - 2, 4 - 1. At the conclusion of the end one of the teams must definitely get "0" points. Sometimes it is seen that both teams cannot score at the conclusion of the end. Ends where both teams do not score points and result in 0 - 0 are called "blank end". The points obtained at the conclusion of each end are added to the scoreboard and the team with more points at the conclusion of the game wins the game. Scoring is explained in detail in the table below.

| Team | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yellow | 2 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 2 | | **7** |
| Red | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | | **5** |

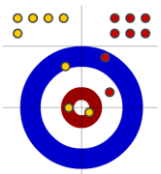

**Figure 3.** First end

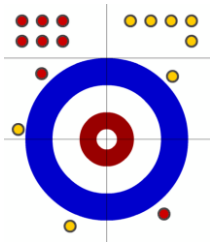

**Figure 4.** Second end

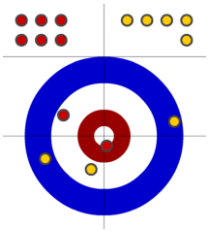

**Figure 5.** Third end

As seen in ***Figure 3***, at the end of the first end, the stones closest to the center of the house belong to the yellow team. For any team to score at the conclusion of an end, at least 1 stone must touch the house after 16 stones have been delivered. Therefore, it is judged that the end will not result in 0 - 0, as there is a stone that touches the house. In order to decide which team gets points, the team whose stone is closer to the center of the house is determined. The yellow team will score as the stone (s) of the yellow team are closer to the center of the house. Then to decide how many points the yellow team gets we have to look at the stone closest to the center of the red team. Since the yellow team has 2 stones closer to the center of the house than red, the yellow team gets 2 points (see Table 3).

***Figure 4*** shows that at the end of the second end, none of the teams stones do not touch the house. In this case, both teams will get "0" points and a "blank end" situation will occur. If the stones do not touch the house, it does not matter which team's stone is closer to the house. In this example, even though the stone of the yellow team is closer to the house than the stone of the red team no points can be scored because, as a rule, a stone of a team must touch the house in order to score points.

In ***Figure 5***, at the end of the third end, it is seen that one stone of the red team is closer to the center of the house than the yellow stones. In this case, the yellow team's stone closest to the center of the house is taken as reference, and stones the red team has closer to the center of the house is counted. In this example, the red team gets 1 point because 1 red stone is closer than yellow. Other ends are evaluated in this way and scores are put on the scoreboard.

### *Hammer*

One of the most important factors in the game is to have the right to throw the last stone of the end. This shot is called “hammer” (Kostuk & Willoughby, 2006). In order to decide which team will throw the last stone in first end, teams throw 2 stones to the center of the house after 9 minutes pre game practice, provided that they have to rotate stones one clockwise and the other counter clockwise. The purpose of these shots is to be able to place the stone closest to the center of the house. The distance of both stones delivered in the name of the teams to the center of the house is measured and recorded with special measurement tools. The average distance of the stones to the center of the house is measured and calculated by the umpires, and the team with a less average distance is given the right to throw the last stone (hammer) for the first end of the game. In other words, the team whose stones are closer to the center of the house will have the right to throw the last stone in first end. Since the hammer right is a very advantageous shot, it changes hands from time to time between the teams to ensure justice in the game. A team that cannot score points from an end as per the rules has the right to throw the last stone of the next end. In other words, the team that gets points from the end has to throw the first stone in the next end. If the end is a blank end (0 – 0) the team holding the hammer right continues to keep this advantage in the next end.

### *Free guard zone rule*

In the second half of the 20th century, the teams that had hammer could take their opponents' stones out for 9 ends (blank end) and threw their last stone of the final end in the house to finish the game with 1 point. Games played in this way could only be won by having good shot percentages without requiring too much thinking, tactics and strategy (Brazeau, 2019). As the curling game had become monotonous and boring over time the Canadian curling players Russ and Glenn Howard (brothers who were on a quest to add excitement to the game) in 1990 developed the Free Guard Zone rule, also called Moncton Rule (Howard, 2010). According to the rule, the stones delivered by the 1st players of both teams (first four stones of the end) in a certain area of playing field (The area between the hog line and T line not including the house as shown in the picture) were forbidden to be taken out by opponent (Ito & Kitasei, 2015). The stone of the team that violated the rule would be taken out of play, and all the stones it touched would be replaced to their original position. In this way, the number of stones in play increased, allowing players more moves, and the game became more enjoyable. In this respect the Free Guard Zone has taken its place in curling history as a very important rule. In order to make the game even more enjoyable the WCF revised this rule in 2018 forbiding the removal of oppositions stones until 5 stones have been played. This was an increase of 1 stone from the previous 4 Rock Rule.

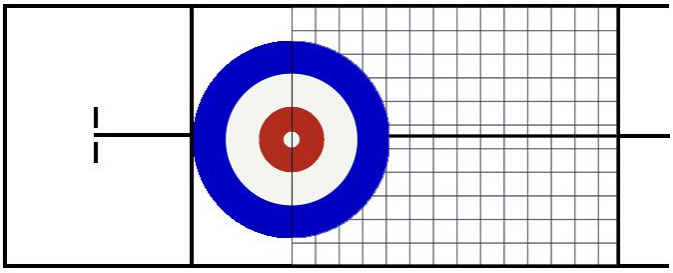

**Figure 6.** Free guard zone shown in shaded area

***Shots***

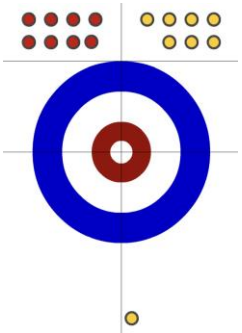

**Figure 7.** Guard

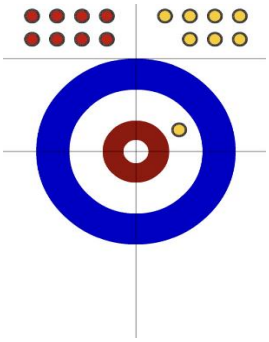

**Figure 8**. Draw

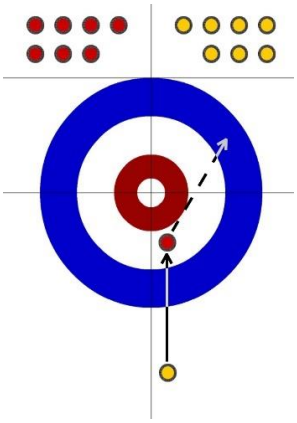

**Figure 9.** Take – out

***a) Guard***

As the name suggests, guard shots are generally stones positioned in front of the stones inside the house. It should be thrown slower than other shots. If the athlete throws the stone to be thrown faster by the guard, the stone may pass the free guard zone or get into the house or go out of play. Stones can be placed in the free guard zone to prevent the opponent team from removing our own stones thrown into the house. In this way, when the opponent team wants to take our stone out of the game in the house, the guard stones make it difficult, the possibility of the opponent to make mistakes increases. Thanks to the FGZ rule, guards can be played in advance to close the area where we plan to throw stones later. Stones placed away from the center line are called corner guards and stones placed close to the center line are called center guards.

***b) Draw***

Draw is the shot that target the house directly. Since the stones must touch the house in order to score the most commonly thrown shot type in the game is draw shots. For this reason, the fourth players should have a very good draw ability.

***c) Take out***

These are usually stones thrown to remove the opposing team's stones from play. Sometimes teams may have to take their own stones out of play by throwing take-outs. Take outs should be thrown faster than other shots. In single, double and triple take out throws, one, two or three stones can be taken out of play.

***Strategy and tactics***

Due to the restrictions imposed on the game by the Free Guard Zone rule athletes have to think a few moves ahead when considering stone placement. However, the athletes who develop many strategies focused on leaving as many difficult situations as possible and getting points from this by forcing the opponent to make mistakes when the opponent will throw the last stone in the end. The team that owns the hammer has tried to develop appropriate strategies to throw the last stone more easily. Since it is very important to have the hammer, sometimes the teams deliberately throw out the last stone of an end where they can get 1 point and may want to finish the end 0 – 0. In this way, the hammer of the following end will remain with the same team along with its advantage. A team will want to give the hammer to the opponent in the next end by taking 2 or more points. Since hammer is an extremely important factor in the curling game, studies (Ahmad et al., 2016; Kostuk & Willoughby, 2006; Kostuk et al., 2001; Park & Lee, 2013) on this concept are available in the literature. With the impact of hammer and Free Guard Zone rule, 3 different types of strategies have emerged. These are called defensive, offensive and blended strategies. While a team that uses defensive strategy allows the opponent or itself to score less by removing the opponent's stones from play, teams that use offensive strategy plan to get more points from that end by ensuring that there are as many stones as possible in play. It is also necessary to know that trying to apply the offensive strategy also risks getting more points for the opponent. The more points a team wants to get

the more risk it will take so teams using offensive strategies should take this factor into consideration. The blended strategy can be described as a mixture of both system. Teams playing with these strategies can instantly change their tactics according to the end, stones remaining to be played, position of stones, ice conditions and score. Since curling is a dynamic game it is extremely important to be able to predict which moves the opponent can make as there is absolutely no room for fixed-mindedness. That is why today teams determine the moves they will make according to the situation of the game instead of playing with a fixed strategy. The sport of curling always attracts more attention because it is a sport in which social/mental processes such as communication, psychological soundness, reasoning, analytical thinking, problem solving, evaluating by remembering the previous shots, seeing the weaknesses of the opponent and acting accordingly. Therefore, the strategies implemented depend greatly on these factors.

### *Curling and scientific research*

Despite its long history, curling is less popular and well-known than sports such as football/soccer, basketball, tennis and athletics. This situation has also been reflected in the scientific research on the sport of curling. There are scientific research areas such as engineering, movement and training, and psychology in curling.

For example, changing ice structure in curling has been studied from an engineering perspective. Despite almost a century of research, there is no exact answer to the question of what exactly causes a stone to curl after it is thrown. Many studies have hypothesized on this issue, but none have been able to quantitatively explain the exact magnitude of the observed rotation. Recently tribology researchers from Uppsala University in Sweden, who often studied friction and abrasion, discovered that the interaction of stone and ice resembles a car tire that follows the grooves of a tram track. According to this discovery it is suggested that the stone, which produces microscopic scratches in the ice surface, curls due to its microscopic roughness (Nyberg et al., 2013). Lozowski et al. (Lozowski et al., 2016), used Inertial Measurement Unit (IMU) sensors to reveal the dynamics of the curling stone. They aimed to reveal a digital model of this movement by capturing the movements of the stone on the ice through the sensors they mounted on the stone. As a result of the research, it was seen that although all angular movements of the stone were successfully obtained by means of sensors, it could not be modeled precisely in any way. In another study conducted recently, it was investigated whether the trail left by the curling stone on the ice had an effect on the course of the stone in subsequent shots. In this context, the researchers examined the course of the curling stone by leaving tracks on the ice in different directions. The findings have shown that the marks left by the curling stone do not significantly affect the subsequent shots (Shegelski & Lozowski, 2019).

Although the factors affecting the curling stone's rotation on ice could not be revealed clearly a group of researchers from the University of Korea designed robots that use artificial intelligence using the information obtained from research in this field. These robots are trained on computer games in which rocks and ice are physically simulated. Robots won three of four games against some of Korea's leading women's teams and the national wheelchair team (Won et al., 2020).

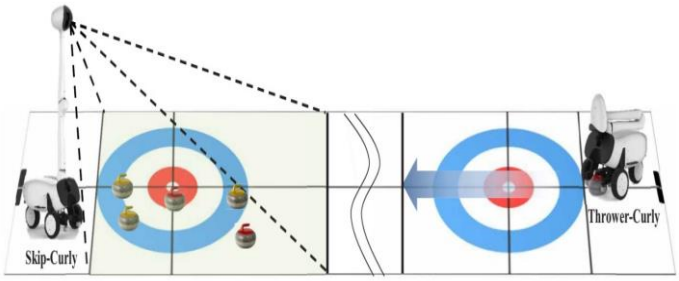


**Figure 10.** Artificial intelligence-powered curling robots (Won et al., 2020)

Although the factors affecting the trajectory of the curling stone on the ice surface are not known exactly, it is possible to affect this by sweeping in the game. Sweeping is perhaps the most exciting and critical phase of curling. Since the sweeping process is of great importance for the teams to score, the researchers studied the most effective sweeping patterns. Marmo et al. (Marmo et al., 2006) developed a model to determine the most effective sweeping style in their study. This model was used to compare the thermal effects of two popular sweeping styles (high and conventional low angle style). The movements of the brooms were monitored by the sensors attached to the brooms. In addition, laboratory-based friction tests were performed to determine the temperature increase caused by the friction of brooms on ice surface. Although most of elite athletes believe high attack angle sweeping style is more efficient, as a result of the findings obtained, it was revealed that the most effective sweeping style was sweeping with the conventional low attack angle style.

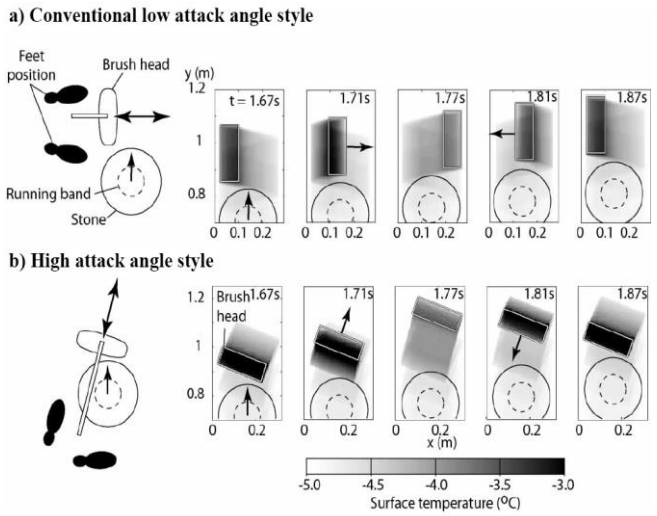


**Figure 11.** Thermal footprint produced by two popular sweeping styles with a schematic representation of the feet and brush position (Marmo et al., 2006)

In addition to sweeping styles, the body shapes of athletes when throwing stones are among the factors that affect success in curling. Yoo, Kim, and Park (Yoo et al., 2012) biomechanically examined the sliding performance of elite

and sub-elite curlers from take-off to releasing the stone in their study. According to the findings, although there was no difference between the groups in the sliding time and horizontal velocity of the body mass center during the sliding, it was observed that there were significant differences between the two groups in the rate of change in the velocity profile of the center of body mass. Although the moment of the body mass center from the anterior / posterior direction to the ankle is positive in elite curlers, it is observed negative in sub-elite curlers. In addition, it was observed that elite curlers had more ankle dorsiflexion and slider foot contact with ice surface. These data show that elite curlers have a superior ability to maintain a regulated speed of movement and balance control during the throwing performance of a curling stone.

The basic motoric characteristics, training conditions and physiological capacities of the athletes are among the factors that affect the success in curling. In this field, Schmid, Lenglet, Guggenheimer, and Blegen (Schmid et al., 2016) examined the changes in heart rate of curlers during the game. According to the findings, the heartbeat intervals of the athletes were 91 +/- 31 bpm in the skip position, 151 +/- 22 bpm while sweeping and 120 +/- 27 bpm while throwing stones. According to the data obtained, it can be said that curling is a sport that uses both aerobic and anaerobic energy systems.

In curling, athletes may have to use their physiological capacities at the maximum level in certain periods of the game. This situation brings the risk of injury to athletes. Although curling seems safer than other winter sports, in the study examining the injuries that occurred in 2016 Lillehammer Youth Olympic Games, more injury percentages were observed from dangerous branches such as figure skating, luge, half-pipe snowboarding and ski jumping (Steffen et al., 2017). Most of the injuries in curling occur during the sweeping process. The reason is thought to be related to repeated upper extremity use as well as constant knee and spine flexion (Reeser & Berg, 2004).

Psychological processes play an important role in the basis of success in curling. Studies have investigated how psychology affects success and team unity in curling. As curling depends on concentration, the fact that the athletes maintain their concentration before and during the game plays an important role in winning the game. In this context, research has focused on the mental preparations of the athletes before and during the game. In particular, data related to the effective use of imagery in curling and its positive results were obtained (Stewart & Hall, 2016; Stewart et al., 2016).

In curling, psychological skills such as making the right decision, establishing effective strategy, communication skills and coping with stress are vitally important for curlers since there is no coach intervention with the athletes after the start of the game. The strategy to be determined during the competition is usually led by the skip and other curlers contribute. Therefore, every athlete's knowledge of strategy is an important factor in dealing with the difficulties encountered in the game. In this context, Westlund and Hall (Westlund & Hall, 2015) developed the "Curling Strategy Assessment Tool" to determine the curling strategy levels of athletes. Thanks to this measurement tool, the strategy knowledge levels of the athletes in the team will be determined and the missing places will be eliminated by the trainings.

## CONCLUSION

The aim of this study is to inform the people about how the sport of curling, a traditional and strategic game, that has a history of 500 years which can easily be played by people of all age groups, explaining the materials used in the game, scoring and its development. In the last 20 years the number of World Curling Federation member associations (countries) has more than doubled and the increase in participants in the Olympics are evidence of the growing interest in curling. In the literature search, no review study explaining the game in general in all aspects was found. With this review, we tried to explain the basic information about curling, which is increasingly popular in the Olympic and Paralympic games, but not much research has been done on the subject. This review will be the basis for the work to be done on the hammer throw preference of athletes, statistical studies on performance, research of the effect of sweeping by engineers and physicists, biomechanical/physiological parameters during delivery and sweeping and psychological processes that are extremely important in curling. In addition we believe that we will contribute to the understanding of the game by providing general information about curling which seems complicated for spectators.

### Acknowledgements

The authors would like to thank Daniel Rafael (Curling DR), Fiona Grace Simpson (The Colored Source) and Ataturk University Sport Sciences Research and Application Center for their support and advice. Anonymous reviewers are also thanked for their contribution to this work.

### *Ethical Statement*

In this article, during the research process, journal writing rules, publication principles, research and publication ethics rules, journal ethics rules were followed. Responsibility for any violations that may arise regarding the article belongs to the author. Since the study was in the nature of a review, no ethics committee application was made.

***Conflict of Interests:*** There is no personal or financial conflict of interest between the authors in this study.

***Author Contributions:*** In this study, while the contribution rate of the correspondence author is 70% and, co-author is 30%.

### References

Ahmad, Z. F., Holte, R. C., & Bowling, M. (2016). Action Selection for Hammer Shots in Curling. IJCAI.

Auld, T., & Kivi, D. (2010). Heart rate recovery in competitive curlers after maximal effort sweeping. In: Thunderbay, ON: *Lakehead University Press*.

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

Braghin, F., Cheli, F., Maldifassi, S., Melzi, S., & Sabbioni, E. (2016). *The engineering approach to winter sports. Springer*.

Brazeau, O. (2019). What is the five-rock rule? The Grand Slam Of Curling. https://thegrandslamofcurling.com/what-is-the-five-rock-rule

Buckingham, M.-P., Marmo, B. A., & Blackford, J. R. (2006). Design and use of an instrumented curling brush. Proceedings of the Institution of Mechanical Engineers, Part L*: Journal of Materials: Design and Applications*, *220*(4), 199-205.

Collins, J., & Durand-Bush, N. (2010). Enhancing the cohesion and performance of an elite curling team through a self-regulation intervention. *International Journal of Sports Science & Coaching*, *5*(3), 343-362.

Collins, J., & Durand-Bush, N. (2014). Strategies used by an elite curling coach to nurture athletes' self-regulation: A single case study. *Journal of Applied Sport Psychology*, *26*(2), 211-224.

Collins, J., & Durand-Bush, N. (2019). The Optimal Team Functioning Model: A Grounded Theory Framework to Guide Teamwork in Curling. *Journal of Applied Sport Psychology*, *31*(4), 405-426.

Curling, S. (2020). History of the game. Scottish Curling. https://www.scottishcurling.org/curling-history/history-of-the-game/

Curling Canada. (2020). 2019 Annual report. https://www.curling.ca/files/2019/09/CC_AnnualReport2019.pdf

Denny, M. (2002). Curling rock dynamics: Towards a realistic model. *Canadian journal of physics*, *80*(9), 1005-1014.

Federation, W. C. (2020a). The rules of curling. *World Curling Federation*.

Federation, W. C. (2020b). Historical results. *World Curling Federation*. https://results.worldcurling.org/

Giovanis, V., & Margari, E. (2015). The evolution of the winter Paralympic games and sports. *Pedagogics, Psychology, Medical-Biological Problems Of Physical Training And Sports* (3).

Grassie, J. (2017). Curling 101: Origins and Olympic history. http://archivepyc.nbcolympics.com/news/curling-101-origins-and-olympic-history

Haggerty, M. (2013). From island to ice: A journey of curling stones. *World Curling Federation*.

Hansen, W. (1999). *Curling: the history, the players, the game*. Key Porter Books.

Hendry, E.R. (2014). Why curling ice is different than other ice. Smithsonian Magazine. https://www.smithsonianmag.com/innovation/why-curling-ice-is-different-than-other-ice-180949752

Howard, R. (2010). *Curl to win: Expert advice to improve your game*. HarperCollins Canada.

Ito, T., & Kitasei, Y. (2015, August 31-September 2). Proposal and implementation of digital curling [Conference presentation]. IEEE Conference on Computational Intelligence and Games (CIG), Tainan, Taiwan. http://cig2015.nctu.edu.tw/

Janik, E. (2010). *A short history of Wisconsin*. Wisconsin Historical Society.

Jensen, E., & Shegelski, M. R. (2004). The motion of curling rocks: Experimental investigation and semi-phenomenological description. *Canadian Journal Of Physics*, 82(10), 791-809.

Jones, C. (2007). Curling secrets: How to think and play like a pro: Nimbus Pub.

Kerr, J. (1890). The History of Curling: And Fifty Years of the Royal Caledonian Curling Club. D. Douglas.

Kostuk, K. J., & Willoughby, K. A. (2006). Curling's paradox. Computers & operations research, *33*(7), 2023-2031.

Kostuk, K. J., Willoughby, K. A., & Saedt, A. P. (2001). Modelling curling as a Markov process. *European Journal of Operational Research*, *133*(3), 557-565.

Lizmore, M. R., Dunn, J. G., & Dunn, J. C. (2016). Reactions to mistakes as a function of perfectionism and situation criticality in curling. *International Journal of Sport Psychology*.

Lozowski, E., Maw, S., Kleiner, B., Szilder, K., Shegelski, M., Musilek, P., & Ferguson, D. (2016). Comparison of IMU measurements of curling stone dynamics with a numerical model. Procedia Engineering, 147, 596-601.

Lozowski, E. P., Szilder, K., Maw, S., Morris, A., Poirier, L., & Kleiner, B. (2015). Towards a first principles model of curling ice friction and curling stone dynamics. The Twenty-fifth International Ocean and Polar Engineering Conference,

Mair, H. (2007). Curling in Canada: From gathering place to international spectacle. *International Journal of Canadian Studies/Revue internationale d'études canadiennes* (35), 39-60.

Marmo, B., & Blackford, J. (2004). Friction in the sport of curling. The 5th International Sports Engineering Conference, Davis, California, September 2004. International Sports Engineering Association, Sheffield,

Marmo, B., Farrow, I., Buckingham, M., & Blackford, J. (2006). Frictional heat generated by sweeping in curling and its effect on ice friction. Proceedings of the Institution of Mechanical Engineers, Part L: *Journal of Materials: Design and Applications*, *220*(4), 189-197.

Mott, M., & Allardyce, J. (1989). *Curling Capital: Winnipeg and the Roarin'Game*, 1876 to 1988. Univ. of Manitoba Press.

Nyberg, H., Sundberg, J., Särhammar, E., Gustavsson, F., Kubart, T., Nyberg, T., Jansson, U., & Jacobson, S. (2013). Extreme friction reductions during initial running-in of WSCTi low-friction coatings. Wear, *302*(1-2), 987-997.

Otani, H., Masui, F., Hirata, K., Yanagi, H., & Ptaszynski, M. (2016). Analysis of Curling Team Strategy and Tactics using Curling Informatics. *icSPORTS*,

Park, S. G., & Lee, S. (2013). Curling Analysis based on the possession of the last stone per end. *Procedia Engineering*, 60, 391-396.

Penner, A. R. (2001). The physics of sliding cylinders and curling rocks. *American Journal of Physics*, *69*(3), 332-339.

Pezer, V. (2007). *Smart Curling: How to Perfect Your Game Through Mental Training*. Fifth House.

Reeser, J. C., & Berg, R. (2004). Self reported injury patterns among competitive curlers in the United States: a preliminary investigation into the epidemiology of curling injuries. *British Journal Of Sports Medicine*, *38*(5), e29-e29.

Schmid, M., Lenglet, K., Guggenheimer, J. D., & Blegen, M. (2016). Descriptive Analysis of Cardiovascular Demands During Elite Curling: 3001 Board# 66 June 3, 3: 30 PM-5: 00 PM. *Medicine & Science in Sports & Exercise*, *48*(5S), 847.

Shegelski, M. R., & Lozowski, E. (2019). Null effect of scratches made by curling rocks. Proceedings of the Institution of Mechanical Engineers, Part P: *Journal of Sports Engineering and Technology*, *233*(3), 370-374.

Steele, A. M., Johnson, B. T., & Kraft, J. (2014). Physical fitness levels for beginning curlers. Research Quarterly for Exercise and Sport, 85(S1), A87.

Steffen, K., Moseid, C. H., Engebretsen, L., Søberg, P. K., Amundsen, O., Holm, K., Moger, T., & Soligard, T. (2017). Sports injuries and illnesses in the Lillehammer 2016 youth Olympic winter games. *British Journal Of Sports Medicine*, *51*(1), 29-35.

Stewart, N. W., & Hall, C. (2016). The effects of cognitive general imagery use on decision accuracy and speed in curling. *The Sport Psychologist*, *30*(4), 305-313.

Stewart, W. N., Kouali, D., & Hall, C. R. (2016). Why athletes use cognitive general imagery in curling: A qualitative investigation. *Journal of Sport & Exercise Psychology*,

Tamminen, K. A., & Crocker, P. R. (2013). “I control my own emotions for the sake of the team”: Emotional self-regulation and interpersonal emotion regulation among female high-performance curlers. *Psychology Of Sport And Exercise*, *14*(5), 737-747.

Turriff, S. (2016). *Curling: steps to success*. Human Kinetics.

Weeks, B. (2020). *Curling for dummies*. John Wiley & Sons.

Westlund, N., & Hall, C. (2015). Item validation of the Curling Strategy Assessment Tool (CSAT). *Journal of Sport & Exercise Psychology*

Wieting, S. G., & Lamoureux, D. (2019). Curling in Canada. In Sport and memory in North America (pp. 140-153). *Routledge*.

Wikipedia. (2020). World Curling Championships. https://en.wikipedia.org/wiki/World_Curling_Championships

Willoughby, K. A., & Kostuk, K. J. (2004). Preferred scenarios in the sport of curling. Interfaces, *34*(2), 117-122.

Won, D.-O., Müller, K.-R., & Lee, S.-W. (2020). An adaptive deep reinforcement learning framework enables curling robots with human-like performance in real-world conditions. *Science Robotics*, *5*(46).

Yoo, K.-S., Kim, H.-K., & Park, J.-H. (2012). A biomechanical assessment of the sliding motion of curling delivery in elite and subelite curlers. *Journal Of Applied Biomechanics*, *28*(6), 694-700.

## GENİŞLETİLMİŞ ÖZET

70 ülkede her yaş grubundan 2 milyondan fazla kişinin oynadığı curling, karışık çiftler kategorisinin olimpiyatlara dahil edilmesiyle daha fazla ilgi görmektedir. İlk kez 16. yüzyılda İskoçya'da donan göller üzerinde oynanan curling sporunun günümüzde en yaygın olduğu ülke Kanada'dır. Curling, olimpiyat oyunlarının özellikle televizyonda en çok izlenen branşlarındandır (Turriff, 2016). Curling sporu ile ilgili birçok farklı konuda araştırmalar yapılmış olmasına rağmen bu branşı tüm boyutlarıyla ele alan ve önemli hususları vurgulayan bir çalışma bulunmamaktadır. Bu çalışmada daha önce yapılmış araştırmalar derlenerek curling hakkında daha detaylı bilgi verilmesi amaçlanmaktadır.

Curling, iki takımın ev adı verilen iç içe geçmiş renkli dairelerin merkezine taş attığı bir buz sporudur (Bradley, 2009). Bowling ve satrancın birleşimi olarak tanımlanan bir kış sporu (Kostuk ve ark., 2001) olan curling, hedef sporları arasında sporcular tarafından hedefe doğru atılan materyale güzergâh üzerinde etki edilebilen tek spordur (Buckingham ve ark., 2006). Buz üzerinde satranç (Haggerty, 2013) olarak adlandırılan oyunda denge, koordinasyon, güç ve dayanıklılık gibi fiziksel özelliklerin yanı sıra (Auld ve Kivi, 2010), zihinsel antrenman (Hansen, 1999), telkin ( Pezer, 2007), iletişim (Jones, 2007;Weeks, 2020), strateji (Weeks, 2020) ve analitik düşünme (Pezer, 2007) gibi özellikler de son derece önemlidir.

Bir curling maçı, her biri "end" olarak adlandırılan 10 bölümden oluşur ve yaklaşık 3 saat sürmektedir. 10 end sonunda rakibinden daha fazla puan alan takım oyunu kazanmaktadır. Normal süre içinde takımlar birbirlerine üstünlük sağlayamazsa ekstra end oynanır. Ekstra endde beraberliği bozan takım oyundan galip ayrılmaktadır. Olimpiyatlarda veya Dünya Şampiyonalarında madalya kazanabilmek için yaklaşık 14 maç oynandığı dikkate alındığında, şampiyona boyunca madalya almak için en uzun performans gerektiren sporun 35 saatlik süreyle curling olduğu ifade edilebilir (Bradley, 2009).

Curling'te oyunu fazla puan farkıyla kazanmanın önemi olmadığı için averaj sistemi yoktur. Bu nedenle sporcular çok puan kazanmak yerine sadece 10 end sonunda oyunu kazanmaya odaklanmaktadır. Bu durum sporcuların daha stratejik düşünmelerini gerektirmektedir. Curling oyunu, sheet adı verilen 45.72 m uzunluğunda 5 m genişliğinde bir alanda oynanır. Takımlar satrançta olduğu gibi sırayla hamle yapmak durumundadır. Sırası gelen sporcu, ayağını hack adı verilen kauçuktan yapılmış takozlardan birine yerleştirdikten sonra taşla birlikte kayar ve taşı sheetin diğer tarafındaki eve doğru atmaktadır.

End sonunda (16 taş atıldığında) amaç, rakibin evin merkezine en yakın taşından daha yakına mümkün olduğu kadar fazla taş biriktirmektir. Puan almanın ilk şartı, end sonunda taşın eve değmesidir. Eve değmeyen taşlar skor olarak değerlendirilmez.

Uzun geçmişine rağmen curling, futbol/futbol, basketbol, tenis ve atletizm gibi sporlardan daha az popülerdir. Bu durum curling sporu üzerine yapılan bilimsel araştırmalara da yansımıştır. Curling sporunda mühendislik, hareket ve antrenman, psikoloji gibi bilimsel araştırma alanları en fazla çalışılan konuların başında gelmektedir.

20 yıl önce Dünya Curling Federasyonu'na üye ülke sayısı 40'a yakınken, bu sayı günümüzde 70'e yükselmiştir. 2018 Kış Olimpiyat Oyunları'na karışık çiftler branşının dâhil edilmesi, curling sporunun hızla yayıldığının ve ilgi gördüğünün en önemli göstergelerinden biridir. Bu çalışmayla Olimpik ve Paralimpik oyunlarda popülaritesi giderek artan curling hakkında temel bilgilerin açıklanması amaçlanmıştır. Bu derleme, curling sporunda çekiç atış tercihi, atış performansı, süpürmenin etkisi, atış sırasındaki biyomekanik/fizyolojik parametre ve psikolojik süreçlerle ilgili bilimsel çalışmalara temel oluşturacaktır. Çalışmada ayrıca seyirciler için karmaşık görünen curling ve puanlama hakkında genel bilgilerin verilmesi oyunun anlaşılmasına katkı sağlayacaktır.