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RESEARCH ARTICLE

Understanding Coaches' Knowledge Acquisition about Skilled Performance in Overhead, Single-Handed Fly-Distance Casting

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ABSTRACT

The performance objective of fly-distance casting is to cast the line as far as possible. The technique has evolved with limited biomechanical analysis, and that conducted has focused on the upper body only. There has been no movement patterning comparison with other sports. Since the 1980s, performance in the ICSF Event 2–38-gram fly-distance casting event at world casting championships has plateaued. The aims of this study were to identify the views of casting coaches (1) about the similarity of fly-distance casting technique to other sports, (2) the determinants of optimal fly-casting distance performance, (3) the role of biomechanics in the development of fly-distance casting technique, and (4) the sources used, and barriers encountered in expanding knowledge. Javelin was the sport most similar to fly-distance casting; line speed was a key performance determinant, and translation, rather than a rotation, was advocated. Coaches agreed biomechanics would be beneficial to performance. Coaches rated little research being available, being unaware of how to access research information and research readability as barriers to knowledge accessibility. This study is the first to identify what fly-casting coaches perceive as the determinants of casting technique, performance and coaching. It establishes a benchmark for further research in areas such as biomechanics, motor learning and sports performance.

Keywords: Casting sport, coaches access to fly casting knowledge, fly-distance casting, tournament fly casting.

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1. Introduction

Fly fishing, as it is known today, was first practised on UK and European streams and rivers in the 1800s to catch trout, grayling, and salmon. Casting distances were short, usually in the range of 5 metres to 25 metres in length. As fly fishing expanded to freshwater lakes and then to saltwater locations, distance casting became a prerequisite to angling success. Along with the growth of fly fishing, competition tournament fly casting or casting sport emerged as an avenue for competition, and the International Casting Federation (later the International Casting Sport Federation-ICSF) was created in 1952 to facilitate casting competitions worldwide.

ICSF world casting championships in overhead, single-handed fly-distance casting comprises annual championships for the 38-gram-sinking line event and biennial championships for both a 5-weight-floating line and a 27-gram floating line event. In overhead, single-handed fly-distance casting, the caster moves the line backwards and forwards in the air until the caster perceives the line has achieved optimal line speed and the loop's optimal shape and trajectory. The line is then cast forward and released from the non-rod hand after the haul motion has been completed (see Fig. 1). The momentum of the final forward cast loop pulls an extra line (previously laid on the water or grass) out through the rod guides whilst the loop is unfolding. The line loop extends fully, and the line, leader, and fly drop to the surface. In fly-distance casting, performance is defined for the purposes of this study as

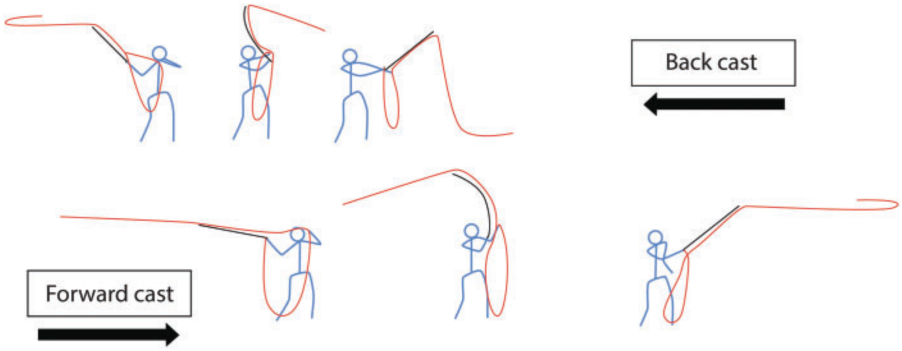

Fig. 1. Back cast and forward/delivery cast cycle.

the straight-line distance between the fly and the caster across the water or grass surface. The casting movement cycle is illustrated in Fig. 1.

1.1. Casting Sport Technique

There have been relatively few reported changes in overhead, single-handed fly-casting techniques in the last 100 years. The last significant change was the introduction of the double haul in the 1930s. Prior to the introduction of the double haul, casters used a single haul or a no haul technique. The double haul was introduced to fly-distance casting competition in the 1934 US national casting championships by Marvin Hedge (Wulff, 1987). The pull or haul on the line by the contralateral hand as the rod rotated increased line speed and is now a staple of fly-distance technique for both recreational anglers and casting sport athletes. ICSF Event 2-38-gram line overhead, single-handed fly-distance casting performance, as measured by gold medal winning scores at casting sport world championships, has plateaued in recent decades, and the lack of innovation in technique has contributed to that outcome. For the 5-weight, long-belly, floating line event, introduced in 2010, most casters use a wider arc than is traditionally used in recreational overhead fly-distance casting. This wider arc technique has been termed the 170 technique and has also been used by ICSF Event 2-38-gram overhead, single-handed fly-distance casters since the 1980s.

1.2. Athlete and Coach Knowledge Acquisition in Casting Sport

Improving performance is a central role of a sports coach, involving a key focus on the athlete's technique. Smith *et al*. (2015) suggested that coaches use a model of an appropriate movement pattern to compare an athlete's performance. To our knowledge, no research has identified what casting coaches perceive as the substance of optimal casting technique. No data has been collected about how instructors view the role sports science, such as biomechanics, motor control, and physiology, may have in fly-distance casting development or the sources instructors and coaches access to expand their knowledge of fly-distance casting technique. To establish where casting is currently positioned on a continuum of skill acquisition and knowledge growth, it is important to identify coaches' perceptions about what body movement patterns deliver optimal casting performance. Understanding the role of biomechanics in coaches' teaching methods may assist in finding possible gaps in both the technique used and coaching strategies employed to optimise performance.

This study aims to explore coaches' perceived optimal teaching technique for overhead, single-handed fly-casting performance, emphasising their use of biomechanics principles as part of their teaching methods. Specifically, the aims were to identify:

1) casting coaches' perception of the similarity of overhead, single-handed fly-distance casting to other sports,
2) casting coaches' view of determinants of optimal overhead, single-handed fly casting distance performance,
3) casting coaches' view as to the role of biomechanics in the development of overhead, single-handed fly-distance casting techniques,
4) the sources casting coaches use to enhance their knowledge base and the barriers they face in doing so.

To our knowledge, no research has been conducted to-date identifying casting coaches' view of what a model of overhead, single-handed fly-distance casting performance technique should consist of. This study aims to redress that deficiency.

TABLE I : Survey Questions Posed to Casting Coaches

Aim	Questions posed to coaches
Similarity to other sports	• To what degree do you believe the fly-distance casting movement is similar to the movements seen in baseball pitching, tennis serving, passing a football by a quarterback in US football, javelin, discus, driving off the tee in golf or bowling a cricket ball?
Determinants of performance	• Do you believe line speed = rod tip speed + haul speed? • How important is line speed to performance? • To what extent does each of the following body segments contribute to line speed-haul hand, rod arm wrist, rod arm elbow, shoulders, hips, knees, or feet? • Should the hips and shoulders rotate together during the delivery cast? • How important are each of the following movements to fly-distance performance-linear movement vs rotational movement, extend the rod hand as far as possible in front of the shoulder before line release, forearm and the wrist rotate together, or separately on the delivery cast, forearm rotates before wrist, start the forward delivery cast with the rod arm bent at the elbow? • What motion initiates the delivery distance cast-the rod hand moves forward in the direction of the cast, and body weight transfers from back to front foot? • In order to deliver maximum distance, which stance would you advocate (assume a right-handed caster)-stepping forward with right foot on the delivery cast, not stepping but left foot is forward on the delivery cast, not stepping but right foot is forward on the delivery cast, stepping forward with left foot on the delivery cast? • What changes as the length of the line aerialised increases? Does the total stroke length increase? Does linear body movement increase? Does haul length increase? Does rotational body movement increase?
Biomechanics	• To what extent do you believe biomechanics research has been used for fly-distance casting performance improvement, technique development, and fly-distance instructional enhancement? • How useful do you believe biomechanics research has been in performance improvement, technique development and instructional enhancement in these other sports–javelin, golf, tennis, baseball, US football, cricket, and discus? • Would these aspects of distance casting benefit from biomechanical research–increased performance, enhanced instructional expertise effectiveness, and reduction in injury? • To what degree do you agree that each of the following inhibits your access to biomechanics research relating to distance casting–no research has been conducted, and I don't know where to go to access research information, available research is not easily readable.
Knowledge acquisition	• Where do you go to expand your knowledge of distance casting technique-attendance at competition fly casting events, fly casting videos, fly casting clinics or seminars, national or international casting sport organisations, certified casting instructors, casting certification organisations, non-certified casting instructors, instructors/coaches of other sports, other sports literature, other sports videos, other sporting organisations, other sports clinics, seminars or conferences?

2. Method

2.1. Participants

A total of 34 participating coaches were identified to be eligible for the study. Participants were Fly Fishers International (FFI), Master Casting Instructors (MCI), and casting coaches from nations affiliated with the International Casting Sport Federation (ICSF). A total of 32 male participants completed the survey. The participants were sourced from 13 countries with a mean age of 63.4 ± 11.7 years and reported being active as casting coaches for a mean of 24.8 ± 13.4 years.

2.2. Study Design

A survey was developed using the Qualtrics online survey platform (www.qualtrics.com) and distributed to individual casting coaches by email. Responses were collected within the Qualtrics platform. The survey comprised 57 questions associated with this study's aims. The survey questions were selected based on the corresponding author's 50-year experience as an overhead, single-handed fly-distance casting competitor in casting sports events and a casting coach. The specific questions used in this study are listed in Table I.

The study comprised four aims. The first aim consisted of 7 questions targeting what coaches perceive as the level of similarity between fly-distance casting and other sports. This data provides a key benchmark from which the determinants of casting performance, the role of biomechanics in casting, and coaches' casting knowledge growth can be compared. The second aim consisted of 25 questions to identify what coaches perceive as the determinants of casting performance. Questions were related to the importance of line speed, the movement pattern that generates line speed, the movement segment that initiates the cast, the body stance, and the extent of scaling due to increases in the length of the line serialised during the cast. The third aim consisted of 13 questions examining biomechanics' role in the development of casting techniques. The benefits biomechanics has provided other sports, the potential benefits of biomechanics to casting, and the barriers to the accessibility of biomechanics research. The study's fourth aim consisted of 12 questions to identify the sources coaches use to expand their fly-distance knowledge base. Each question asked the participant to respond using a slider scale of 0 to 100. Zero is total disagreement with the question's contention, and 100 is total agreement.

2.3. Statistical Analysis

Survey data was extracted from the Qualtrics platform, and deidentified data was transferred to an Excel spreadsheet. The Excel spreadsheet was then imported into R Studio (TRStudio Team, 2020) for statistical analysis. The median, quartiles, mean, and standard deviations were calculated for each response and collated under the relevant study's aim.

3. Results

The data from coaches' responses to the survey questions were skewed, so the median and the IQR were used to report the survey data.

3.1. Aim 1: Identify Casting Coaches' Perception of the Similarity of Overhead, Single-Handed Fly-Distance Casting to Other Sports

Table II shows how coaches ranked the similarity between overhead, single-handed fly-distance casting and seven other throwing or hitting sports. Javelin 86 (24.5) was the sport ranked most similar to fly-distance casting, while discus 23 (43.0) was ranked as the least similar.

3.2. Aim 2: Identify Casting Coaches' View of the Determinants of Optimal Overhead, Single-Handed Fly-Distance Casting Performance

Table III shows the movement patterns coaches perceived as determining casting performance and the rankings they applied to those movements. Line speed was considered a key determinant of performance 83 (29.3) and was derived from the rod tip speed plus the haul speed 91.5 (10.3). Hips and shoulders rotating together 97.5 (12.0), followed by translation in the direction of the cast 91.6 (19.0), then the forearm rotating before the wrist 90.0 (69.0) and a straight arm in front of the shoulder 90.0 (27.5) at line release were the preferred movement patterns. Rotation around a central vertical axis through the body 60.0 (55.5) was considered the least important movement pattern for optimal performance.

3.3. Aim 3: Identify Casting Coaches' Views as to the Role of Biomechanics in the Development of Overhead, Single-Handed Fly-Distance Casting Technique

Table IV shows the role biomechanics has had in overhead, single-handed fly-distance casting technique development, training and coaching. Coaches were neither supportive nor unsupportive of the role biomechanics had played in the development of casting technique, training and coaching to-date 50.0 (55.0) but considered biomechanics would deliver beneficial outcomes in areas of (a) performance 99.0 (24.5), (b) coaching expertise 97.0 (21.8), and (c) injury reduction 90.0 (38.0), if used in the development of overhead, single-handed fly-distance casting technique in the future. Casting coaches perceived biomechanics had been more beneficial to each of the nominated 7 throwing or hitting sports than it had been in the development of overhead, single-handed fly-distance casting technique, training and coaching.

TABLE II : Similarity of Casting to Other Sports

Category	Subcategory	Median	1st Q	3rd Q	Mean	SD
Other sport	Javelin	86.0	71.0	95.5	80.1	21.9
	Baseball	71.0	50.0	82.0	63.5	28.1
	US football	52.5	47.0	76.3	56.2	24.9
	Tennis	47.0	22.5	66.8	44.9	29.4
	Golf	40.5	16.3	60.0	41.4	31.0
	Cricket	23.0	6.5	49.5	30.1	29.9
	Discus	23.0	7.5	50.5	32.9	30.7

TABLE III : THE DETERMINANTS OF FLY-DISTANCE CASTING PERFORMANCE

Category	Subcategory	Median	1st Q	3rd Q	Mean	SD
Line speed	Line speed = rod tip speed + haul hand speed	91.5	89.8	100	89.7	11.2
	Importance of line speed	83.0	70.8	100	81.1	16.9
	Contribution to line speed from					
	Haul hand	100.0	89.0	100	90.8	19.1
	Rod arm wrist	92.0	79.0	100	83.5	24.0
	Rod arm elbow	89.0	72.3	100	83.0	20.3
	Shoulders	63.0	43.5	76.5	60.2	26.9
	Hips	48.5	20.0	71.0	50.6	31.7
	Knees	28.0	14.0	41.0	37.5	25.2
	Feet	27.5	12.0	50.0	37.5	33.1
Movement patterning	Hips and shoulders rotate together	97.5	88.0	100	86.9	35.9
	Linear translation in the direction of the cast	91.6	81.0	100	87.0	18.1
	Straight rod arm in front of shoulder at line release	90.0	71.8	99.3	79.2	27.4
	Forearm rotates before the wrist	90.0	30.0	99.0	68.1	20.2
	Flexed rod arm elbow at the back	77.5	49.5	90.3	62.4	33.1
	Rotation around the central vertical axis through the body	60.0	36.0	91.5	62.9	30.8
Initiating movement	Body weight shift	92.0	82.5	100	86.3	21.1
	Hand moves forward	90.0	20.0	100	52.2	35.9
Stance	Stepping with ipsilateral leg	86.0	57.8	99.3	75.6	29.7
	No step–contralateral leg forward	85.0	60.0	99.3	71.8	35.1
	No step–ipsilateral leg forward	15.0	15.0	80.3	49.5	32.1
	Stepping with the contralateral leg forward	14.5	1.50	87.5	41.8	42.0
Scaling*	Total stroke length	94.0	80.3	100	83.2	26.2
	Linear body movement	90.0	63.0	100	77.9	28.4
	Haul length	84.5	47.5	100	68.3	35.2
	Rotational body movement	70.0	48.0	89.3	63.0	31.4

Note: *Movement changes are advocated as line length aerialised during false casts increases.

3.4. *Aim 4: Identify the Sources Casting Coaches Use to Enhance their Knowledgebase and the Barriers they Face*

Table V shows the sources that coaches use for casting knowledge acquisition and the barriers that they face in doing so. Coaches favoured casting-related knowledge sources, namely competitions at 90.0 (20.0), videos at 75.0 (40.0), and clinics and seminars at 74.0 (76.0). Non-casting sources, such as other sports coaches at 22.5 (44.8), other sports literature at 9.0 (17.5), and other sports videos at 5.5 (44.3), were least preferred.

4. DISCUSSION

The aims of this study were to identify casting coaches' view of (1) the similarity of overhead, single-handed fly-distance casting to other sports, (2) the determinants of optimal distance casting performance, (3) the role of biomechanics in the development of casting technique, and (4) the sources coaches used to enhance their knowledge base and the barriers they face in doing so. Using a survey comprising questions the contributing author saw as reflecting overhead, single-handed fly-distance

TABLE IV : The Role of Biomechanics in Casting To-Date, Future Benefits and Barriers to the Accessibility of Biomechanics Research

Category	Subcategory	Median	1st Q	3rd Q	Mean	SD
Fly-distance casting	Extent of use in casting to-date	50.0	22.5	77.5	51.3	33.0
Benefits to casting	Performance	99.0	75.5	100	86.4	17.9
	Coaching expertise	97.0	78.3	100	84.4	20.0
	Injury reduction	90.0	62.0	100	80.7	22.5
Benefits to other sports	Discus	100	75.0	100	83.7	26.6
	Javelin	98.0	77.5	100	88.2	16.5
	Golf	91.0	78.0	100	86.3	17.1
	Tennis	85.5	75.0	100	85.3	14.9
	Baseball	85.0	72.8	100	83.1	16.7
	US. Football	80.0	72.0	100	79.4	21.9
	Cricket	78.0	70.0	100	79.2	17.9
Barriers	No research available	80.0	30.0	87.0	61.6	23.3
	Don't know how to access research	76.0	50.0	100	68.2	33.0
	Not easily readable	60.0	48.3	90.0	62.6	30.5

TABLE V : The Sources Coaches Use to Expand their Casting Knowledge

Category	Subcategory	Median	1st Q	3rd Q	Mean	SD
Casting sources	Competitions	90.0	80.0	100	83.9	21.7
	Casting videos	75.0	50.0	90.0	66.3	26.4
	Clinics or seminars	74.0	15.0	91.0	57.9	37.9
	Casting sport associations	65.5	47.5	81.3	59.6	30.7
	Certified coaches	55.5	20.0	84.5	54.6	35.6
	Certification bodies	49.0	0	90.0	39.9	34.8
	Non-certified coaches	45.0	2.5	79.8	44.1	37.8
Non-casting sources	Coaches of other sports	22.5	5.3	50.0	29.0	26.5
	Sports literature	9.0	3.8	21.3	18.7	23.6
	Other sport videos	5.5	0.8	45.0	24.4	30.8
	Sports organisations	4.0	0	12.0	13.8	23.9
	Sports clinics	1.0	0	20.0	17.7	31.0

casting movement patterns and coaching strategies observed over 50 years as a competitor at all levels of national and international casting sport competitions was considered an acceptable method by which to achieve all 4 study aims. To our knowledge, this study is the first to examine each of the above aims. Hence, no comparison can be made with other similar studies about overhead, single-handed fly-distance casting. However, comparisons to studies of other sports have been made.

Sports science and specifically biomechanics, has been used in many sports to improve performance and technique, including baseball (Fortenbaugh *et al.*, 2009), cricket (Bartlett *et al*., 1996b), javelin (Morriss & Bartlett, 1996), discus (Leigh *et al*., 2008) tennis (Knudson & Elliott, 2004), and golf (Hume *et al*., 2005). Despite a number of research studies conducted into the biomechanical analysis of throwing sports, a paucity of studies have been conducted into fly-distance casting. Although the caster uses a fly rod to propel the line forward in the delivery cast, it is feasible to describe the movement employed as similar to the movement used in throwing sports like javelin or a hitting sport like serving a tennis ball. In throwing sports, such as javelin (Morriss *et al*., 1997), the faster the release speed of the object thrown, the further it will travel. In the case of hitting sports, such as golf (Fradkin *et al*., 2004) or tennis (Colomar *et al*., 2022), the faster the club head or racquet is moving at the point of impact with the ball, the further the ball will travel.

Fly-distance casting performance is measured by the distance the line travels forward before landing on the water, and therefore, the line speed is a key determinant (Röijezon *et al*., 2017). The result of this study establishes the opportunity for comparisons of both movement patterning and biomechanical principle compliance in overhead, single-handed fly-distance casting with that of other throwing and hitting sports. From such a comparative benchmark, casting opportunities to improve technique and performance can be established.

4.1. Aim 1: Similarity of Overhead, Single-Handed Fly-Distance Casting to Other Sports

In order to compare the movement pattern of fly-distance casting to other throwing sports, it was important to establish those sports which casting coaches considered similar to overhead, single-handed fly-distance casting. This study selected seven sports to compare with fly-distance casting. The selected sports included both throwing and hitting sports. Each sport selected used speed as the determinant of performance, e.g., the speed of the hand at release or the speed of the equipment used at impact. This study found casting coaches considered javelin and baseball as the sports most similar to overhead, single-handed fly-distance casting, whilst bowling a cricket ball and discus throwing were considered the least similar. In casting, the fly line is propelled forward in the overhead, single-handed fly-distance delivery stroke just as a javelin or baseball is propelled forward in the javelin throw or baseball pitch. The concept of the kinetic chain (Seroyer *et al*., 2010) and the principle of the summation of speed (Neal *et al*., 1991) used to generate release speed are common to each sport selected for comparison to casting. The speed of the rod tip equates to the racquet speed in tennis, or club head speed in golf. Fleisig *et al*. (1996) found that all throwing sports utilise a proximal to distal movement pattern to transfer energy to the object being thrown. Allen *et al*. (2008) reported fly casting shows a proximal to distal movement patterning involving the shoulder, elbow and wrist of the ipsilateral casting arm from 18 casters over distances up to 24.4 metres.

Identifying javelin and baseball as the sports most similar to casting provides the opportunity to compare the hand speed generated in casting to javelin and baseball. A comparison of the movement patterning used in javelin, baseball and casting will identify the proximal to distal movement opportunities casting coaches can use to improve performance. For that to occur, it was necessary to identify coaches' perceptions of the casting movement patterning that delivers the longest casts possible. Those key casting performance determinants were examined in Aim 2.

4.2. Aim 2: Overhead, Single-Handed Fly-Distance Casting Performance Determinants

This study explored coaches' perceptions of line speed, movement patterning, the cast's initiating movement, stance, and scaling as important factors in casting performance.

4.2.1. Line Speed

Whilst height and angle of release of the javelin or baseball impact the distances thrown, research has identified that release velocity is the most important determinant of throwing performance (Bartlett, 2000; Bartlett *et al*., 1996a; Viitasalo *et al*., 2003; Worthington *et al*., 2013). It was, therefore, important to first identify whether casting coaches considered line release speed as a key determinant of performance in overhead, single-handed fly-distance casting. Secondly, they need to establish their view on how line speed is defined and the movement pattern used to generate it, and thirdly, they need to identify views on stance and any scaling that will impact movement structure and performance.

The objective of overhead, single-handed fly-distance casting performance is to cast or throw the fly line as far as possible. There was general agreement amongst casting coaches that line speed 83.0 (29.25) was the major determinant of the distance cast. Coaches also agreed that line speed was the sum of the speed of the rod tip plus the speed of the hauling hand at the point of line release 91.5 (10.3). Unlike throwing sports like javelin or baseball, in overhead, single-handed fly-distance casting the object thrown does not maintain a constant shape. The line is flexible and changes shape as the loop forms and straightens in flight. Whilst the rod tip speed is a result of the ipsilateral rod hand movement, the line is also accelerated by the contralateral haul hand movement prior to line release (Röijezon *et al*., 2017). The use of both the ipsilateral and contralateral hand to directly accelerate the object thrown, in this case, the fly line, is unique to fly casting. Maximising line release speed by coordinating the line release from the haul hand to coincide with the highest rod tip speed (Röijezon *et al*., 2017) provides the caster with the best chance of achieving optimal casting distance.

Coaches' perceptions about the extent to which different body segments contribute to line speed indicate the casting stroke follows a proximal to distal pattern for the ipsilateral shoulder, elbow, and wrist. The contralateral haul hand 100 (11.0), ipsilateral wrist 92.0 (21.0), elbow 89.0 (27.8) and shoulder 63.0 (33.0) were considered the primary sources of line speed. Hips 48.5 (51.0), knees 28.0 (27.0) and feet 27.5 (38.0) were rated as contributing relatively less to line speed. The relative rankings of body segment contributions to line speed indicate a preference for speed to be generated from both ipsilateral and contralateral upper body movement. It is reasonable to assume that casting coaches focus their instruction on the upper body, with relatively little focus on how the lower body can contribute to rod tip and line speed. Establishing line speed as a key determinant of casting performance but having a relatively low contribution of the lower body to line speed compared to the upper body creates an opportunity for coaches to fully examine the impact on the performance of a full body, proximal to distal casting movement pattern.

4.2.2. Movement Patterning

Whilst coaches identified javelin and baseball as the sports most similar to overhead, single-handed fly-distance casting, the survey results identify a number of differences in the movement patterns used in casting compared to those sports. Coaches consider translation in the direction of the cast more important to maximum performance than rotating the body around a central, vertical axis. In contrast, baseball performance is based on trunk rotation around the spine (Hong *et al*., 2001), and in the javelin, the hips and shoulders rotate around the longitudinal axis of the trunk (Navarro *et al*., 1998). Wagner *et al*. (2011) found pelvis and shoulder angular velocities were major contributors to ball speed in handball. Aguinaldo and Escamilla (2019) found trunk rotation was a significant predictor of ball speed in baseball. Rotating the hips before the shoulders is a fundamental of the proximal to distal pattern of both force production and transfer in throwing sports (Fleisig *et al*., 1996).

The perception in overhead, single-handed fly-distance casting that the hips and shoulders should rotate together is contrary to the rotational-based movement used in other throwing sports. Urbin *et al*. (2013) found that internally rotating the hips before rotating the shoulders facilitated the creation of elastic energy that was then transmitted through the throwing arm to the hand in overarm throwing. Having the hips and shoulders rotate together limits that potential. Transferring force from the lower body into the upper body, then to the throwing hand, is the foundation of throwing sports (Aguinaldo & Escamilla, 2019). However, casting coaches advocate a proximal to distal force production pattern only between the forearm and wrist. Not utilising the full body patterning employed in other throwing sports limits the opportunity to optimise the line speed and, hence, casting performance.

A number of studies have examined the ipsilateral elbow movement patterning in javelin throwing. Campos *et al*. (2004) found throwers at the 1999 World Championships extended the elbow of the throwing arm to increase the path length over which the javelin was accelerated. Chen *et al*. (2020) also linked javelin acceleration to the thrower extending their throwing arm elbow at the start of the impulse stage of the throwing movement. Casting coaches advocate a flexed rod arm at the start of the delivery stroke. Casting coaches prefer the ipsilateral rod arm elbow to be flexed at the start of the forward release stroke but favour a fully extended elbow at the point of line release in the forward release stroke. It could be concluded that casting coaches focus on extending the accelerating hand path in front of the shoulder rather than behind the shoulder, which is the pattern used in other throwing sports.

4.2.3. Initiating Movement

Casting coaches favour initiating the overhead, single-handed fly-distance delivery casting stroke with distal segment movement rather than proximal segment movement, i.e., shifting the body weight 92 (17.5) and moving the rod hand forward 90 (80.0) to start the cast. In contrast, other throwing sports employ a movement pattern favouring a proximal to distal movement sequence in which the throwing hand is the last segment of the movement chain to move forward. Advocating a flexed arm at the start of the casting stroke reduces the length over which the rod hand can be accelerated, resulting in lower speed at release (Campos *et al*., 2004). Initiating the casting stroke by shifting the body weight establishes a linear-based patterning that inhibits the ipsilateral hip rotation used in other sports to trigger proximal to distal force production. Establishing the movements which initiate the casting stroke contributes to the aim of identifying the determinants of optimal casting performance.

4.2.4. Stance

The stance in throwing and hitting sports is the platform upon which the proximal to distal movement pattering is established. Coaches were asked to rate various stance and stepping options concerning which delivered optimal casting performance. Stepping with the ipsilateral foot 86 (41.5) or not stepping but with the contralateral foot forward 85 (39.3) was considered important to overhead, single-handed fly-distance casting performance. Stepping with the contralateral foot at 14.5 (86.0) or not stepping but with the ipsilateral foot forward at 15.0 (65.3) were not favoured. Coaches favour using a different leading foot depending on whether they advocate a static stance or a stepping movement for overhead, single-handed fly-distance casting. Whilst an open stance is preferred for optimal performance, there is a perception that either stance is effective for optimal casting performance. However, stepping with either foot is less favoured than hand and arm movement, which initiates the delivery cast.

Observation of javelin throwing and baseball pitching reveals that athletes use the contralateral foot as the leading foot in the throwing or pitching movement pattern. Stodden *et al*. (2006) found that hip rotation is restricted when the athlete steps forward with the ipsilateral foot during the throw, and consequently, the angular velocity generated is reduced. Stepping with the contralateral foot facilitates rotational movement of the trunk (Stodden *et al*., 2006) and enhances the proximal to distal throwing sequence. In contrast, casting coaches favour stepping with the ipsilateral foot when a step is incorporated into the casting delivery stroke. If no step is included in the casting delivery stroke, casting coaches advocate that the contralateral leg is in front of the ipsilateral leg during the delivery stroke. This study did not explore the reason casting coaches advocate a different leading leg posture for a step versus a static stance posture in overhead, single-handed fly-distance casting. Casting coaches recognise that rod tip speed contributes to line speed. Advocating stepping with the ipsilateral leg during the delivery stroke is contrary to the findings of Stodden *et al*. (2006), who found that performance improved when the contralateral foot was in front of the ipsilateral foot when throwing. The foot placement preferences coaches advocate for casting are incongruous compared to other sports. This finding is important when considering the impact on both rod hand and haul hand speed generation and the resulting impact on line speed. An opportunity exists to identify the impact of stance and stepping options on hand speed generation and casting performance.

4.2.5. Scaling

Coaches favoured increasing the total stroke to 94 (19.8) and haul length to 84.5 (52.5) as the line length aerialised increases. They also advocated increasing linear or translational body movement 90 (37.0) compared with rotational body movement 70 (41.3) as the appropriate scaling strategy. The preference for increasing linear movement over increasing rotational body movement follows the general theme of the data, which suggests that casting coaches do not favour the rotational-based movement pattern used in other throwing sports.

Van Den Tillaar and Ettema (2004) observed that handball athletes did not change their coordination patterns when using different ball weights. It is reasonable to conclude that scaling some aspects of the movement pattern used in overhead, single-handed fly-distance casting reflects the properties of the flexible fly line being thrown or cast, compared to throwing a concentrated mass like a ball. Identifying what aspects of the caster's movement pattern they advocated be changed as line length increases contributes to determining optimal casting performance.

4.3. Aim 3: The Role of Biomechanics in the Development of Technique, Potential Benefits, and Barriers to the Accessibility of Biomechanics Research

Biomechanical analysis of sport movement patterns has been used to improve performance in many sports. In outlining biomechanics' role in tennis technique development, Elliot (2002) found biomechanics was central to player performance. How casting coaches view biomechanics' role in casting technique development and what benefits biomechanics could deliver are important considerations if performance improvements are to be achieved in the future.

Coaches were neither supportive nor unsupportive 50 (55.0) of the extent to which biomechanics had been used to optimise casting performance. Coaches were in general agreement that biomechanics would be beneficial to fly-distance casting performance. Five throwing and two hitting sports were selected for coaches to rate how beneficial biomechanics had been to each sport. Discus 100 (25) and javelin 98 (22.5) were considered the sports which had benefited most from biomechanics although coaches rated each sport at, or above a median value of 78 on the scale 0 to 100.

The different perceptions casting coaches had about the extent to which biomechanics had been used in overhead, single-handed fly-distance casting to-date, and their response to the potential benefits biomechanics could offer casting, indicates casting coaches support biomechanics research being used to enhance casting performance. Waters *et al*. (2019) identified a need for biomechanics to engage more fully with running coaches in order to better disseminate research findings amongst coaches. Reade *et al*. (2008) found accessibility to sports sciences a major barrier in their survey of coaches from several sports. Knudson (2007) refers to coaches and biomechanics having a shared objective of performance improvement and fewer injuries and challenges both the coaching and biomechanics communities to establish a definitional framework to assist coaches in equating what they know from their coaching experiences with the findings of biomechanics research. Casting coaches ranked few research articles being available, 80 (57.0), not knowing how to access research articles 76 (50.0), and research being difficult to read 60 (41.8) as barriers to accessing research information. This study suggests Knudson's comments are equally relevant to fly-distance casting coaches. The challenges of transferring knowledge between coaches and scientists, as identified by coaches of other sports, exist similarly in casting. These findings highlight the barriers coaches perceive may inhibit the dissemination of biomechanics knowledge to casting coaches and athletes.

4.4. Aim 4. The Sources Coaches Use to Expand their Fly-Distance Knowledge Base

The various sources coaches use to access casting knowledge are important in deciding how new knowledge can best be distributed to coaches and athletes. The challenges casting coaches perceive as applying to knowledge acquisition are not unique to casting sports. Casting coaches' responses were similar to the findings of Williams and Kendall (2007), who surveyed coaches of Olympic summer sports about their needs as elite coaches. The authors found that sports scientists and coaches shared an objective of improving athletic performance but identified issues with the readability of the data and how the information was disseminated. Coaches primarily access specific information sources for knowledge. Attending casting tournaments 90 (20.0), casting videos 75 (40.00) and casting clinics and seminars 74 (76.0) indicate a preference for experiential and observational-based learning environments. Thompson *et al*. (2009) found a similar preference from a survey of sprint coaches and found coaches wanted information relevant to their coaching. Thompson *et al*. (2009) suggest the need to identify how coaches interact with opportunities for new knowledge acquisition and how they rationalise the usefulness, or otherwise, of new knowledge they access. Casting coaches' perceptions exemplify that need. Coaches rated casting sports associations 65.5 (33.8) and certification bodies 48.5 (90.0) regarding their confidence level in making research available. Casting sports associations and certification bodies are key stakeholders in disseminating knowledge to coaches and athletes. Both directly contact coaches and athletes through casting competitions, videos, clinics and seminars. The level of confidence coaches had in such bodies making research available would indicate a potential disconnect that would need further investigation. This study presents an opportunity to further study how future casting research can be most effectively disseminated to coaches and athletes.

5. Conclusion

Overhead, single-handed fly-distance casting technique has evolved without a fully integrated lower and upper body kinematic study being conducted into the body movement patterning employed. The studies conducted to-date have focused primarily on shoulder-to-wrist patterning. Since the 1980s, performance in Event 2, single-handed, fly-distance casting using a 38-gram line in world championships has plateaued. To the authors' knowledge, this study is the first to identify how instructors coach and the knowledge sources they access, to improve performance. The study established key data from which comparisons were made with other sports about technique and performance, and the data provides a benchmark for future evaluation of the level of compliance that the current overhead, single-handed fly-distance casting technique has to biomechanical principles. Although casting has had little engagement with sports science to-date, the study found that coaches acknowledged that biomechanics would enhance casting performance. This study establishes future research opportunities for sports scientists, as well as a skill enhancement opportunity for recreational fly fishers, casting sports athletes and coaches. Further research is needed to identify full body kinematics of fly-distance casting performance and compare that to the kinematics of other throwing athletes, such as javelin throwers.

6. Limitations

Instructors and coaches who were either not certified by Fly Fishers International (FFI) or had no affiliation with national casting sports organisations were not invited to participate. The online survey format did not allow for a discussion about participant responses. The survey provided qualitative responses from participants only.

7. Delimitations

Inviting only FFI-accredited instructors and casting sports coaches affiliated with the International Casting Sport Federation to participate in the survey allows access to a broad and extensive casting knowledge information base. Using a scale from 0 to 100 for each question allowed each participant flexibility in responding to questions posed. Having participants from a number of different countries reduces the risk of any regional coaching bias.

Conflict of Interest

The author declares that there is no conflict of interest.

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