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**Fit for golf**  
**A literature review of the link between  
physical fitness and golf performance**

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## **Abstract**

### **Title:**

Fit for golf

A literature review of the link between physical fitness and golf performance

### **Background:**

Despite the physical requirements of the golf swing, there hasn't been much focus historically on the role of physical fitness in golf performance. However, attitudes have changed. Based on logic, as well as clinical experience, it's rather clear that physical fitness makes a difference to golf performance. But, from a scientific point of view, what findings have been made?

### **Purpose:**

To explore what research has said about the link between physical fitness and golf performance.

### **Study design:**

Literature review

### **Method/material:**

12 studies from the databases PubMed, Cinahl, AMED and PEDro were selected and analyzed. Inclusion criteria were scientific articles in English or Swedish, published during the past seven years. The search terms included golf, golf performance, exercise, physical training, physical characteristics, strength training and physical fitness.

### **Result:**

Physical fitness characteristics, studied in relation to golf performance, included flexibility, muscular strength, muscular endurance, balance/stability and cardiovascular performance. Significant correlations with golf performance were found for all these characteristics, and most frequently between total body rotational power and clubhead speed. However, few studies looked at the same correlations, and in some cases results were inconsistent. Seven studies looked at physical training interventions; overall body conditioning programs, focusing primarily on flexibility and muscular strength. All training interventions significantly improved golf performance in terms of increased clubhead speed. In addition, significant improvements of physical fitness characteristics, such as torso rotation flexibility and strength, lower body strength, and balance were demonstrated.

### **Conclusion:**

Eleven of 12 articles show a positive link between physical fitness and golf performance, highlighting the importance of flexibility, strength and core stability. However, differences in study participants, evaluation methods and training interventions indicate the need for further studies in this field.

### **Key words:**

*golf, physical conditioning, exercise, strength training, muscle stretching*

## **Sammanfattning**

### **Titel:**

I form för golf

En litteraturstudie kring sambandet mellan fysisk kondition och golfprestation.

### **Bakgrund:**

Trots golfsvingens fysiska krav har det tidigare inte varit mycket fokus på vikten av fysisk kondition vad gäller golfprestation. Synen har dock förändrats med tiden. Baserat på såväl logik som klinisk erfarenhet står det ganska klart att en fysiskt vältränad kropp har positiv inverkan på golfprestation. Men vad har man kommit fram till från ett vetenskapligt perspektiv?

### **Syfte:**

Att undersöka vad forskning visat om sambandet mellan fysisk kondition och golfprestation.

### **Studiedesign:**

Litteraturstudie

### **Metod/material:**

12 studier från databaserna PubMed, Cinahl, AMED and PEDro valdes ut och analyserades. Inklusionskriterierna var vetenskapliga artiklar på engelska eller svenska, publicerade under de senaste sju åren. Söktermerna inkluderade golf, golfprestation, motion, fysisk träning, fysiska egenskaper, styrketräning och fysisk kondition.

### **Resultat:**

Fysiska egenskaper, som studerats i samband med golfprestation, inkluderade rörlighet, muskelstyrka, muskulär uthållighet, balans/stabilitet och kondition. Signifikanta samband med golfprestation uppvisades för alla dessa egenskaper, och mest frekvent mellan hela kroppens rotationskraft och klubbhastighet. Det var emellertid få studier som undersökte samma samband och i vissa fall var resultaten motsägelsefulla. Sju studier tittade på fysiska träningsprogram; helkroppsprogram med fokus på framför allt rörlighet och muskelstyrka. Alla träningsinterventionerna förbättrade golfprestationen signifikant. Dessutom uppvisade man signifikanta förbättringar av fysiska egenskaper som t ex rörlighet och styrka i bålrotation, styrka i underkroppen, samt balans.

### **Slutsats:**

Elva av 12 artiklar visar ett positivt samband mellan fysisk kondition och golfprestation, och lyfter fram vikten av rörlighet, styrka och bålstabilitet. Skillnader i studiedeltagare, utvärderingsmetoder och träningsinterventioner visar dock på behovet av fler studier inom det här området.

### **Nyckelord:**

*golf, fysisk kondition, fysisk aktivitet, styrketräning, muskelstretching*

## Dictionary

### Abbreviations

Hcp: Handicap

EMG: Electromyographic/electromyography

### Golf terminology [13, 14, 15]

Amateur: Opposite of professional, one who does not receive monetary remuneration from the game.

Backspin: Reverse spin applied to the ball, preventing it from bouncing forward after landing.

Bunker: This hazard area is a dug out area filled with sand. Typically a ball hit into a bunker will be slowed by the sand and remain in the bunker thereby penalizing the golfer by preventing the ball's further travel. Also known as a "sand trap".

Carry distance: Distance a golf ball travels in the air before striking the ground.

Chip shot: A short approach shot hit into a green.

Club: Piece of golf equipment consisting mainly of a shaft, a grip and a club head used to strike the ball around the golf course.

Clubface: The hitting surface of a clubhead.

Clubface angle: The angle of the clubface at impact.

Clubhead: The metal or wood portion of the club located at the end of the shaft used to actually hit (make contact with) the golf ball. Includes the clubface.

Drive: A golf shot hit from the tee typically with a driver, or 3-wood.

Driving range: Area typically adjacent to a golf course where golfers may practice their golf shots or warm up by hitting balls into a designated area.

Golf: A game in which a player hits a small ball from the tee into the cup on the putting green on each hole in as few strokes as possible by striking the ball with clubs to propel it.

Golf course: The area used to play golf which consists of tees, fairways, greens, sand traps and other hazards.

Golf hcp: The number of shots a golfer may deduct from his score at the end of a round for comparison purposes. A handicap allows golfers of different abilities to compete together. A golfer's handicap is based on several factors but in simple terms it is basically equivalent to

the average number of strokes above par that a golfer scores for a complete round over time.

Green:	The putting surface which contains the cup and the flagstick and extremely short grass intended for putting.
Greens in regulation:	Playing one's ball onto the green in the prescribed number of strokes as determined by par (equal to par for the hole minus two strokes for putting). Example: Hitting the green in regulation would mean the ball is on the green in one shot on a par 3, two shots on a par 4 and three shots on a par 5.
Hole:	The cup on a putting green into which a golfer attempts to hit the golf ball to complete a hole. Also, a part of a golf course typically consisting of a tee, fairway, and green. There are 18 holes on a standard golf course.
Impact:	The period during which a ball is in contact with the clubface during a golf shot.
Launch angle:	The initial trajectory of the ball relative to the ground.
Par:	The designated number of strokes for a given hole that an expert golfer should complete a hole in. Also, the designated number of total strokes an expert golfer should complete a round in. Par is typically 72 on a standard golf course.
Pitch:	A short golf shot hit often into a green with a high trajectory and lots of spin.
Putt:	A short golf shot typically made on the putting green where the golf ball is struck and rolled toward the hole with a club (putter) that has an extremely flat clubface.
Professional golfer:	A golfer who plays for money and/or plays golf on the professional tour.
Recreational golfer:	An amateur golfer, at any skill level, who play for fun in his/her free time.
Sand shot:	A shot played from a bunker.
Sand trap:	Also known as a bunker, an area on a golf course filled with sand that is intended to catch and hold errant golf shots.
Short game:	Important part of a golfer's game that is comprised of pitching, chipping and putting.
Score:	The number of strokes taken on a hole or course.
Swing:	To move one's golf club with the intention of hitting a golf ball.

Target accuracy: Percentage of shots that hit the target.

Tee: The name for the designated area where a player may hit his/her initial shot on a given hole.

Trajectory: The arching path a golf ball travels when hit.

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## 1. Background

*“You must work very hard to become a natural golfer.”*

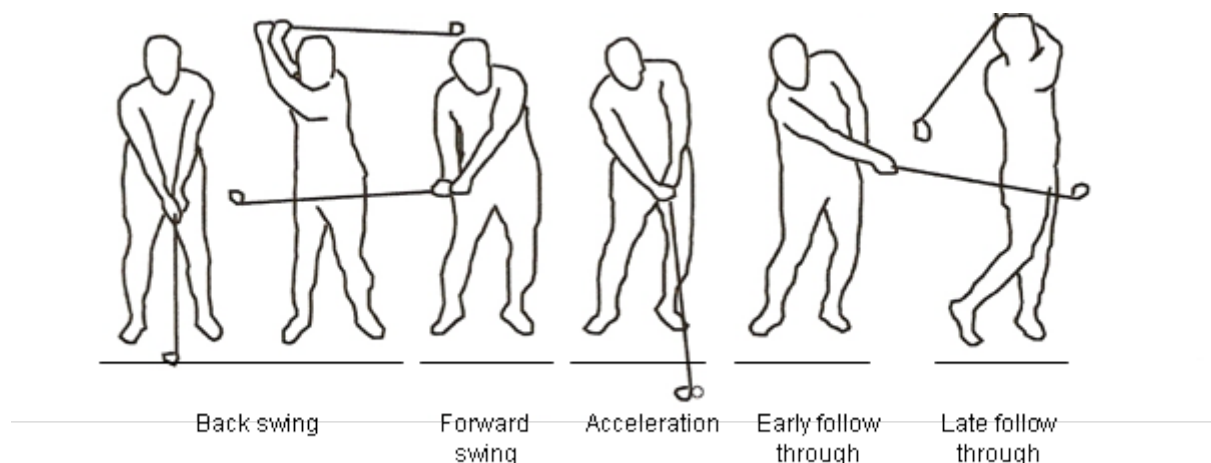
**Gary Player**

Golf is a sport that has grown extensively during the past 50 years. In Sweden alone there are about 500,000 golfers, and the number of golfers worldwide is estimated at around 60 million [1, 2]. Some of these play golf full time as professionals or elite amateurs. However the majority are recreational golfers, who play for fun in their free time.

Golf is enjoyed by people of all ages. It's suitable also for the elderly, and many continue to play when they're in their 60's and 70's, sometimes even their 80's. In addition to the physical activity and the benefits of being outdoors for several hours, golf provides an important social forum.

### 1.1. The golf swing

The golf swing involves the whole body and is a complex movement. It requires a range of different coordinated muscle activities. The most active muscles are located in the torso, shoulders and hips. In scientific studies, five phases generally describe the golf swing. (Figure 1) [3].



**Figure 1:** *The golf swing* [3, 8]

EMG studies of highly skilled golfers have shown which muscle activities dominate throughout these phases (depending on swing technique and skill level, these muscle activities may vary) [3]:

#### *Phase 1: Back swing*

The shoulder girdle rotates to the right (for a right-handed player), and in this phase, the upper body muscles are the most active, including for example trapezius, subscapularis and serratus anterior.

#### *Phase 2: Forward swing (early down swing)*

In preparation to hit the ball, the body now returns back to the ball. This movement is initiated by the hips, rotating the pelvis. Gluteal-, leg-, and pelvic muscles, as well as scapula stabilizers and pectoralis major play important roles in this phase.



### *Phase 3: Acceleration (late down swing)*

Being the most active phase, the golf swing now continues down to ball impact. The pectorales are the most active muscles of the upper body. Just before impact, there is a combined right wrist flexion and forearm pronation, and the activity in the wrist flexors largely increases. This is termed the “flexor burst”. The lumbopelvic stabilizers are also highly active in this phase, providing a solid base for the trunk to rotate.

### *Phase 4: Early follow through*

This phase starts after ball impact and is characterized by deceleration of trunk rotation. Pectoralis major, as well as trunk- and shoulder rotators are active. Following the “flexor burst” in the previous phase, there is now a left arm supination and right arm pronation, controlled by the rotator cuff. In the lower body, the left side provides a stable base and the the right side rotates around it.

### *Phase 5: Late follow through*

The muscle activities in this phase are similar to those in the early follow through. However, approaching the end of the swing, muscle activities decrease. Several muscles work eccentrically during the follow through to support the deceleration of body and golf club [3].

In addition to coordinated muscle activities, the golf swing also requires flexibility and balance [4].

## **1.2 Golf performance and physical fitness**

Golf performance can be described and measured in different ways. In competitive golf, it's the total number of strokes during a round (the score) that counts. Other ways of looking at golf performance include for example scoring average, ranking points on an order of merit list, driving accuracy, driving distance, clubhead speed or number of putts per round [5]. Golf handicap (hcp) can also be used to determine at what skill level a golfer performs – the lower the hcp, the better the player.

Depending on which measure is used, golf performance is influenced by some or several factors. Golf swing technique is one example. Others include experience, mental strength, level of motivation, dedication and time spent on practicing, talent, weather conditions, equipment, as well as physical fitness [4, 5]. Physical fitness can be defined as “a set of attributes that people have, or achieve, relating to their ability to perform physical activity”. These attributes may include for example muscular strength, flexibility and cardiovascular capacity [6].

Despite the complexity and physical demands of the golf swing, there hasn't been much focus historically on the role of physical fitness in golf performance. Rather, the focus has been on swing technique, tactics and mental aspects of the game [4].

## **1.3 The importance of physical fitness**

Going back a few decades, to the 1980's, not even many of the professional golfers engaged in other physical training than walking the golf course and practicing on the driving range. However, attitudes towards physical training for golfers have changed since then. Nick Faldo, Tiger Woods and Annika Sörenstam are among the players who have paved the way for strength-, stability- and flexibility training to enter into the lives of golf professionals. Today, basically everybody playing on the professional tours, or as elite amateurs, realize the benefits of physical fitness to golf performance – as well as for injury prevention [Interview, Fanny Sunesson, Feb 7, 2011].

It's suspected, though, that the situation is not the same among recreational golfers. Most golfers don't participate in off-season training. Nor do they tend to warm up before heading for the first tee. At the same time, whatever skill level, most golfers seem to have a desire to improve their game [7, 8].

Based on logic – considering the physical requirements of the golf swing – and based on clinical experience of professional golfers, it's quite clear that physical fitness makes a difference to golf performance [9]. But, from a scientific point of view, what findings have been made?

Considering the large number of golfers worldwide, and the ambition of many golfers to improve their game, it would be interesting to know which physical fitness characteristics and what types of physical training that have proven important to golf performance. Working as a physiotherapist you may meet many golfing patients or clients, at all skill levels. Knowing the musculoskeletal system, and the basics of the golf swing, you can help with golf specific physical training, based on people's own physical conditions. Such physical training could help improve not only people's golf performance, but their possibility to maintain an active life-style throughout life, and potentially avoid golf-related injuries.

#### **1.4 Purpose and questions**

The purpose of this study was to explore what research has said about the link between physical fitness and golf performance.

##### *Questions:*

- Which measures of golf performance have been used in this context?
- Which physical fitness characteristics have been studied in relation to golf performance?
- What types of physical training interventions have been studied in relation to golf performance?
- Which significant correlations have been found between physical fitness characteristics and golf performance?
- Which significant improvements of physical fitness characteristics and golf performance have been found as a result of physical training interventions?

#### **1.5 Demarcations**

Being closely related to the purpose of this study, it would have been interesting to explore typical golf injuries and how physical training could help prevent such injuries. However, as time and resources wouldn't allow for this, it hasn't been the intention to incorporate this area into the study.

Also, it hasn't been the intention of this study to analyze different types of golf swing techniques and their relation to physical fitness characteristics and golf performance – although this could be another interesting area to explore further.

#### **1.6 Target group**

The target group of this study is above all students and others at the Department of Physiotherapy at Lund University (or at other universities), who have an interest in either golf or physical training, or both. The study could also be of interest to golfers as well as golf instructors, who would like to review findings when it comes to physical fitness and golf performance.

## 2. Method/material

### 2.1 Search and selection of articles

This study was a literature review. The search for scientific publications on the link between physical fitness and golf performance was made in the databases PubMed, Cinahl, AMED and PEDro. The searches were performed 2010-10-27 and 2010-10-29, using the following search terms: golf, golf performance, exercise, physical training, physical characteristics, strength training and physical fitness. For information on the search strategy, please see Tables 1 and 2 below.

### 2.2 Inclusion criteria

The search included scientific articles in English or Swedish, published during the past five years. All selected articles were to be original publications. In order to be able to include a sufficient number of articles, the search period was extended from five to seven years.

### 2.3 Selection process

- Step 1 Review of all titles found in order to determine relevance of articles. A total of 22 articles were selected.
- Step 2 Abstracts of the relevant articles were read and based on that a selection of eleven articles was made.
- Step 3 In order to ensure a sufficient number of articles for this study the search period was extended to also include 2004-01-01—2005-10-31.
- Step 4 A search for 2004-01-01—2005-10-31 was performed. Four more articles were found to be relevant of which three were selected and added for a total of fourteen articles.
- Step 5 The full texts of all selected articles were read and thereafter two studies were removed (see 2.4), leaving a total of twelve articles for this literature review.

*Table 1: Search for articles from the past five years. Search performed 2010-10-27.*

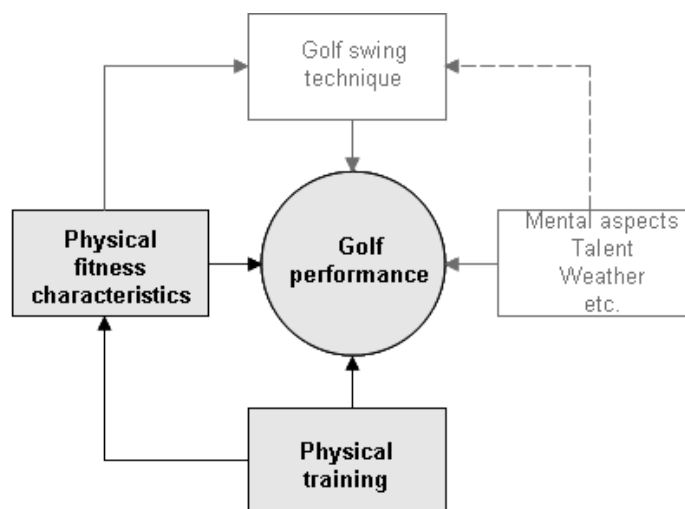
Database	Search strategy	Number of hits	Relevant: New
Pubmed	1. golf performance	104	14
	2. golf AND exercise	55	10: 2
	3. golf AND physical training	29	7: 1
	4. golf AND physical characteristics	13	4: 0
	5. golf AND strength training	11	8: 0
	6. golf AND physical fitness	11	1: 0
Cinahl + AMED	1. golf performance	81	16: 4
	2. golf AND exercise	70	12: 0
	3. golf AND physical training	24	8: 0
	4. golf AND physical characteristics	12	3: 0
	5. golf AND strength training	16	10: 1
	6. golf AND physical fitness	16	2: 0
PEDro	1. golf	6	1: 0
TOTAL		22 relevant	

**Table 2:** Search for articles 2004-01-01—2005-10-31. Search performed 2010-10-29.

Database	Search strategy	Number of hits	Relevant: New
Pubmed	1. golf performance	24	4
	2. golf AND exercise	18	3: 0
	3. golf AND physical training	8	1: 0
	4. golf AND physical characteristics	3	0
	5. golf AND strength training	1	0
	6. golf AND physical fitness	5	2: 0
Cinahl + AMED	1. golf performance	16	2: 0
	2. golf AND exercise	26	2: 0
	3. golf AND physical training	13	2: 0
	4. golf AND physical characteristics	4	0
	5. golf AND strength training	6	1: 0
	6. golf AND physical fitness	5	0
PEDro	1. golf	4	2: 0
TOTAL		4 relevant	

#### 2.4 Final selection of articles

Only articles focusing on physical fitness characteristics or physical training and golf performance were selected. Physical fitness characteristics may influence golf performance indirectly as well, via improved swing technique (Figure 2). However, articles analyzing fitness characteristics in relation to golf swing technique and golf performance were not considered to be within the scope of this study, and were therefore excluded.



**Figure 2.** Selection of articles

Selected articles related only to physical training or physical fitness characteristics and golf performance.

### *Selected articles*

Listed in chronologic order, categorized by key focus.

#### *On physical fitness characteristics and golf performance:*

- A. Keogh, J.W.L., Marnewick, M.C., Maulder, P.S., Nortje, J.P., Hume, P.A., Bradshaw, E.J. Are anthropometric, flexibility, muscular strength, and endurance variables related to clubhead velocity in low- and high-handicap golfers? *J Strength Cond Res.* 2009 Sep; 23(6): 1841-50.
- B. Gordon, B.S., Moir, G.L., Davis, S.E., Witmer, C.A., Cummings, D.M. An investigation into the relationship of flexibility, power and strength to club head speed in male golfers. *J Strength Cond Res.* 2009 Aug; 23(5): 1606-10.
- C. Wells, G.D., Elmi, M., Thomas S. Physiological correlates of golf performance. *J Strength Cond Res.* 2009 May; 23(3): 741-50.
- D. Sell, T.C., Tsai, Y.S., Smoliga, J.M., Myers, J.B., Lephart, S.M. Strength, flexibility and balance characteristics of highly proficient golfers. *J Strength Cond Res.* 2007 Nov; 21(4): 1166-71.
- E. Stemm, J.D., Jacobson, B.H., Royer, T.D. Comparison of stability and weight shift among golfers grouped by skill level. *Percept Mot Skills.* 2006 Dec; 103(3): 685-92.

#### *On physical training, physical fitness characteristics and golf performance:*

- F. Chen, B., Lam, W.K., Mok, D., Yeung, F., Hung, J., Dale, R.B. A three-week conditioning program for improved golf performance. *Athletic Therapy Today*, 2010 Jul; 15 (4): 22-6.
- G. Lephart, S.M., Smoliga, J.M., Myers, J.B., Sell, T.C., Tsai, Y.S. An eight-week golf-specific exercise program improves physical characteristics, swing mechanics, and golf performance in recreational golfers. *J Strength Cond Res.* 2007 Aug; 21(3): 860-9.
- H. Thompson, C.J., Cobb, K.M., Blackwell, J. Functional training improves club head speed and functional fitness in older golfers. *J Strength Cond Res.* 2007 Feb; 21(1): 131-7.
- I. Doan, B.K., Newton, R.U., Kwon, Y.H., Kraemer, W.J. Effects of physical conditioning on intercollegiate golfer performance. *J Strength Cond Res.* 2006 Feb; 20(1): 62-72.
- J. Thompson, C.J., Osness, W.H. Effects of an 8-week multimodal exercise program on strength, flexibility, and golf performance in 55- to 79-year-old men. *J Aging Phys Act.* 2004 Apr; 12(2): 144-56.

#### *On physical training and golf performance:*

- K. Fradkin, A.J., Sherman, C.A., Finch, C.F. Improving golf performance with a warm up conditioning programme. *Br J Sports Med.* 2004 Dec; 38(6): 762-5.
- L. Fletcher, I.M., Hartwell, M. Effect of an 8-week combined weights and plyometrics training program on golf drive performance. *J Strength Cond Res.* 2004 Feb; 18(1): 59-62.

## **2.5 Data review and analysis**

The 12 articles were reviewed by the author. Key content was noted and summarized in a matrix format. In the process of further reviewing the articles, the content of the matrix was revised and updated as needed. The matrix provided a summary overview of the articles that facilitated the work of extracting relevant content for the result chapter.

### 3. Results

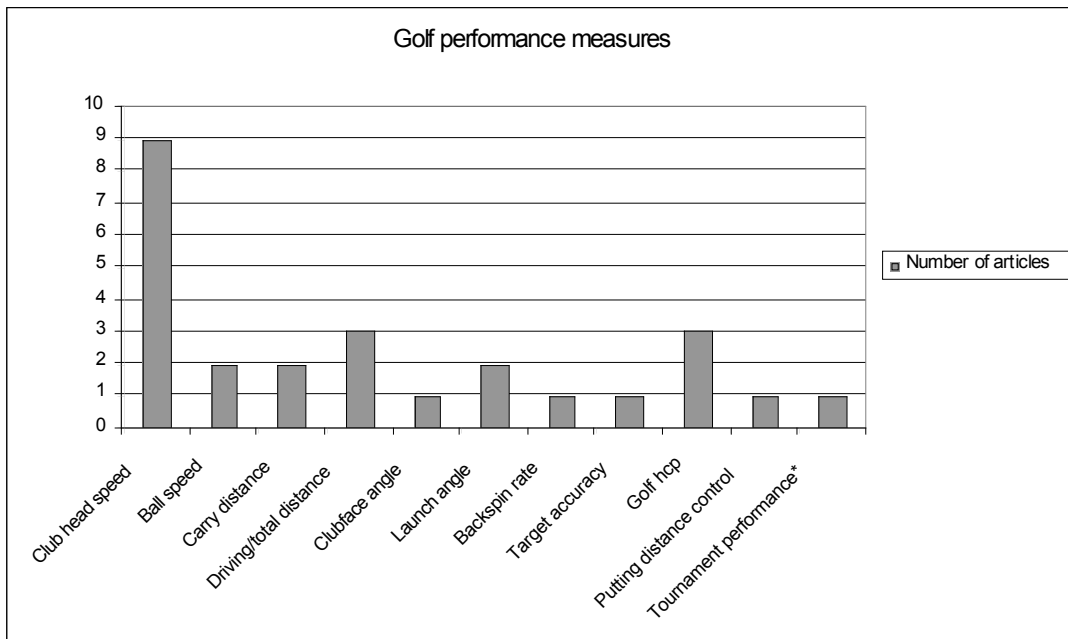
For an overview of the study participants, please see Appendix 1.

#### 3.1 Golf performance measures used

*Which measures of golf performance have been used in this context?*

Several different measures of golf performance are used in relation to physical fitness (Figure 3). Half of the articles include one measure of golf performance; either clubhead speed or golf hcp (B, D, E, H, J, K). The remaining articles include from two to seven measures.

A majority of the articles use clubhead speed as a golf performance measure (A, B, F, G, H, I, J, K, L). Of those that don't, one article uses ball speed, carry distance and tournament measures (C), and two use golf hcp (D, E). Two articles (C, I) include short game measures. One of them studies these under tournament conditions (C), and this is the only article that includes tournament performance measures.



**Figure 3.** Golf performance measures used in the reviewed articles

\* Tournament performance measures include: Mean score, mean number of greens in regulation, average putt distance after a chip shot, average putt distance after a sand shot and mean number of putts per round.

#### 3.2 Physical fitness characteristics studied

*Which physical fitness characteristics have been studied in relation to golf performance?*

Ten articles study physical fitness characteristics, including the following areas: Flexibility, muscular strength, muscular endurance, balance/stability and cardiovascular performance (Figure 4). A majority of the articles in question studies flexibility (A, B, C, D, F, G, H, I, J) and muscular strength (A, B, C, D, G, H, I, J).

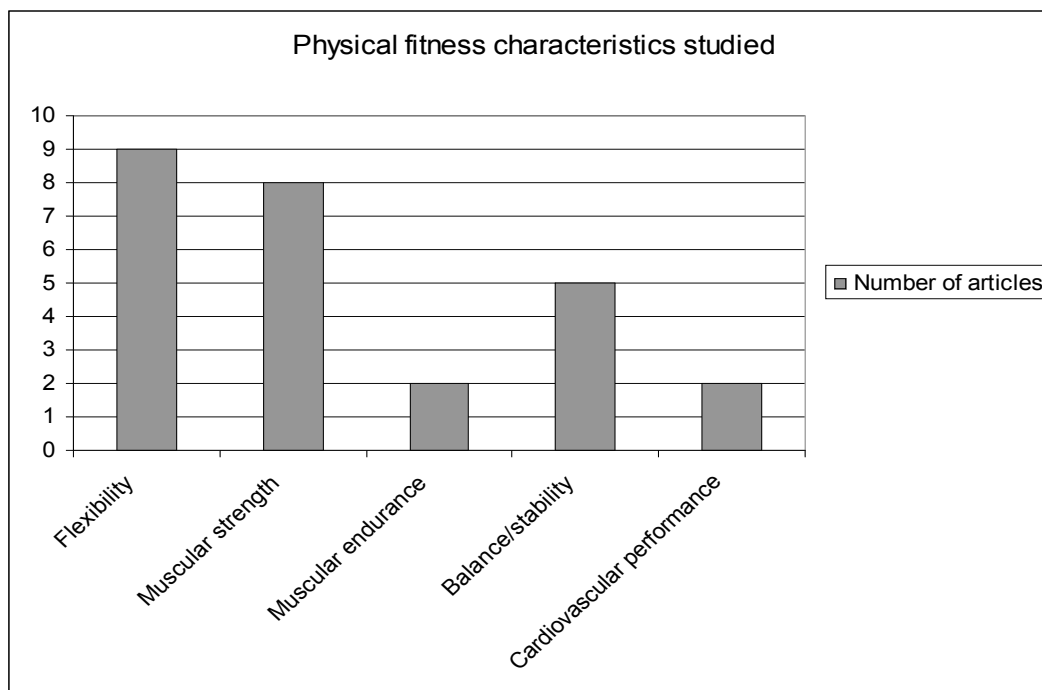
The most commonly studied aspects of flexibility are:

- Torso rotation flexibility (A, B, D, F, G, I, J)
- Hip flexibility (A, D, G, J)

- Shoulder flexibility (D, F, G, J)
- Hamstring flexibility (C, D, G)

All eight articles studying muscular strength, look at different aspects of upper body strength, including for example the strength of arms, shoulders, chest, abdomen and back. Seven of them look at elements of lower body strength such as that of legs and hips (A, C, D, G, H, I, J). Two articles study torso rotation strength (D, G), whereas three articles (A, B, I) look at total body rotational power, evaluating movements that mimic the golf swing.

The most commonly studied aspect of balance/stability is static stability (C, D, E, G). Two articles look at dynamic stability (E, H). In regards to muscular endurance, the endurance of the abdominals is studied (A, C).



**Figure 4.** *Physical fitness characteristics studied*

### 3.3 Physical training interventions studied

*What types of physical training interventions have been studied in relation to golf performance?*

Seven articles look at physical training interventions, as outlined in Table 3. The length of the training interventions ranges from three to eleven weeks, but most last for eight weeks or more (G, H, I, J, L). Two of the training programs are home based (G, K), four are supervised by a certified fitness professional (H, I, L) or primary researcher (J). One program lacks information on this (F).

A majority of the training interventions are described in a detailed manner (F, G, H, I, J), but nevertheless leaves some interpretation to the reader in terms of how to carry out specific exercises. A couple of programs offer less details, and more of an overriding understanding of the training program outline (K, L).

### *Mode*

Six of the training interventions include a range of different muscle strength exercises for upper and lower body, as well as stretching exercises for flexibility (F, G, H, I, J, L). The remaining intervention (K) is a warm up conditioning program, focusing only on flexibility.

All six strength training programs include torso rotational exercises (F, G, H, I, J, L). Five of them do this through total body rotational power exercises, mimicking the golf swing – by throwing a medicine ball (H, I, L), swinging a 1,3 kg club (J) or performing golf swings with a resistive elastic band (G, H). Four programs (F, G, H, I) focus on core stability, although done in slightly different ways, for example by using a vibration platform (F) or a stability ball (H).

Static balance exercises are part of two interventions (G, H). One of them also includes dynamic balance exercises; two-leg hops and single leg hops in the sagittal and frontal plane, holding each landing (H). Stretching exercises differ between the programs, but in most cases aim primarily to increase torso-, shoulder-, chest-, neck-, hip-, and hamstring flexibility. Aerobic exercises are included, as warm up only, in four training interventions (H, J, K, L).

### *Intensity*

Regarding muscle strengthening exercises, only one article describes the intensity in terms of % of RM; in this case 80% or 10-RM (J). The other articles describe the number of sets and repetitions made for each exercise. Four articles explain the progression of the strength exercises over time (H, I, J, L). Stretching exercises are performed between five and 30 seconds. A majority of the training interventions include stretching of 15-30 seconds per stretch (F, G, H, I, J).

### *Frequency*

The frequency of training sessions ranges between two and five per week. Three sessions per week is most common (H, I, J), followed by five sessions per week (F, K).

### *Duration*

The duration of each session varies between five to ten minutes and three hours. However, most commonly, a session is somewhere between 45 and 90 minutes (G, H, I, J, L).

**Table 3.** *Physical training interventions studied*

<b>Article</b>	<b>Mode</b>	<b>Intensity</b>	<b>Frequency</b>	<b>Duration</b>
F.	3-week conditioning program. Not mentioned if home based or supervised. Tailored for the participant of the case study. Designed to enhance flexibility, strength and ability to keep head still during the golf swing. <ul style="list-style-type: none"><li>• Massage</li><li>• Stretching</li><li>• Muscle strength exercises</li><li>• Head alignment training</li></ul>	5 min/muscle for massage  30 s/stretch  3x20 reps for strength and head alignment exercises	5 sessions/week	3 h/session
G.	8-week conditioning program. Home based. Designed to enhance stability of lower body, increase mobility of upper body and improve torso rotational strength. <ul style="list-style-type: none"><li>• Muscle strength exercises</li><li>• Balance exercises</li><li>• Stretching</li></ul>	3x10-15 reps bilaterally for strength exercises  30 s/exercise for balance  30 s/stretch	3-4 sessions/week	Not mentioned, but estimated at approximately 45 min/session (by author of this review)



H.	<p>8-week training program. Led by a certified fitness professional. Focus on spinal stabilization and neuromuscular control during functional movements.</p> <ul style="list-style-type: none"> <li>• Warm up and stretching</li> <li>• Core stabilization</li> <li>• Balance</li> <li>• Muscle strength exercises</li> <li>• Rotational power exercises</li> <li>• Cool-down with stretching</li> </ul>	<p>15-30 s/stretch</p> <p>Progression: Core: From 1x6 to 2x15 reps</p> <p>Balance: From 1x4 to 2x12 reps</p> <p>Strength: From 1x15 to 3x8 reps</p>	3 sessions/week	1,5 h/session
I.	<p>11-week training program. Supervised by a certified strength and conditioning coach first two and last six weeks. Focus on strength, power and flexibility.</p> <ul style="list-style-type: none"> <li>• Trunk strengthening exercises</li> <li>• Resistance training</li> <li>• Stretching</li> <li>• Golf-specific (hitting balls at driving range + putting)</li> </ul>	<p>Progression: Trunk: From between 1x15 - 2x30 reps (depending on the exercise) to between 2x15 – 2x40 reps</p> <p>Resistance: From 3x10-12 to 3x7-9 reps</p> <p>2x15 s/stretch</p>	3 sessions/week	1,5 h/session  Golf specific exercises: minimum of 8 h/week
J.	<p>8-week training program. Supervised by primary researcher.</p> <ul style="list-style-type: none"> <li>• Aerobic warm up</li> <li>• Weight training</li> <li>• Stretching</li> <li>• Golf specific exercise (swinging a 1,3 kg club)</li> </ul>	<p>1x12 reps 80% of 10-RM Increased weights after 12 sessions; in increments of 4,5 kg</p> <p>20 s/static stretch 30 s/dynamic stretch</p> <p>1x10 reps for golf specific exercise</p>	3 sessions/week	Max. 1 h/session
K.	<p>5-week warm up conditioning program. Home based.</p> <ul style="list-style-type: none"> <li>• Warm up</li> <li>• Stretching</li> <li>• Golf specific (airswings)</li> </ul>	<p>4x15 s warm up</p> <p>2 x at least 5 s./stretch for each side of the body</p> <p>30 s of airswings</p>	5 sessions/week + immediately prior to play	Not mentioned, but estimated at 5-10 min/session (by author of this review)
L.	<p>8-week training program. Supervised by a qualified fitness instructor. Designed to affect muscular force and help the sequential nature of the golf swing while maintaining the distance forces act over (maintenance stretching).</p> <ul style="list-style-type: none"> <li>• Warm up</li> <li>• Free weight training</li> <li>• Plyometric medicine ball exercises</li> <li>• Cool-down and stretching</li> </ul>	<p>Weight training: Progression from 3x6 to 3x8 reps. Thereafter increased weight by 5 kg.</p> <p>Plyometric exercises: 3x8 reps</p> <p>12 s/stretch</p>	2 sessions/week	1,5 h/session

### 3.4 Significant correlations between physical fitness and golf performance

*Which significant correlations have been found between physical fitness characteristics and golf performance?*

Six of the ten articles, which study physical fitness characteristics, analyze their link to golf performance (A, B, C, D, E, I). Significant correlations with golf performance are found in all areas of physical fitness characteristics, including flexibility, muscular strength, muscular endurance, balance and cardiovascular performance (Table 4). The physical characteristic most frequently found to be correlated with golf performance is total body rotational power, supported by three studies (A, B, I). In most cases there is only one study supporting a significant correlation.

**Table 4.** Significant correlations found between physical fitness characteristics and golf performance

Physical fitness characteristics		Golf performance measures	Article/s studying this	Article/s showing a significant correlation
<b>Flexibility:</b>				
• Hamstring flexibility	AND	Ball speed Carry distance Tournament performance	C C C	C C C
• Torso flexibility	AND	Golf hcp	D, A	D
• Shoulder flexibility	AND	Golf hcp	D	D
• Hip flexibility	AND	Golf hcp	D, A	D
<b>Muscular strength:</b>				
• Total body rotational power	AND	Clubhead speed Golf hcp	A, B, I A	A, B, I A
• Torso rotation strength	AND	Golf hcp	D	D
• Peripheral muscle strength	AND	Ball speed Carry distance Tournament performance	C C C	C C C
• Chest strength	AND	Clubhead speed	B	B
• Hip strength	AND	Golf hcp	D	D
• Shoulder strength	AND	Golf hcp	D	D
<b>Muscular endurance:</b>				
• Abdominal muscle endurance	AND	Carry distance Tournament performance	C C	C C
<b>Balance:</b>				
• Static balance	AND	Golf hcp Tournament performance	D, E C	D C
<b>Cardiovascular performance</b>	AND	Tournament performance	C	C

### 3.5 Significant improvements as a result of physical training interventions

*Which significant improvements of physical fitness characteristics and golf performance have been found as a result of physical training interventions?*

Five of the seven articles, which study physical training interventions, measure the improvements of physical fitness characteristics as well as golf performance (F, G, H, I, J). The remaining two articles measure the improvements of golf performance only (K, L). All areas of physical fitness characteristics measured, show significant improvements, including

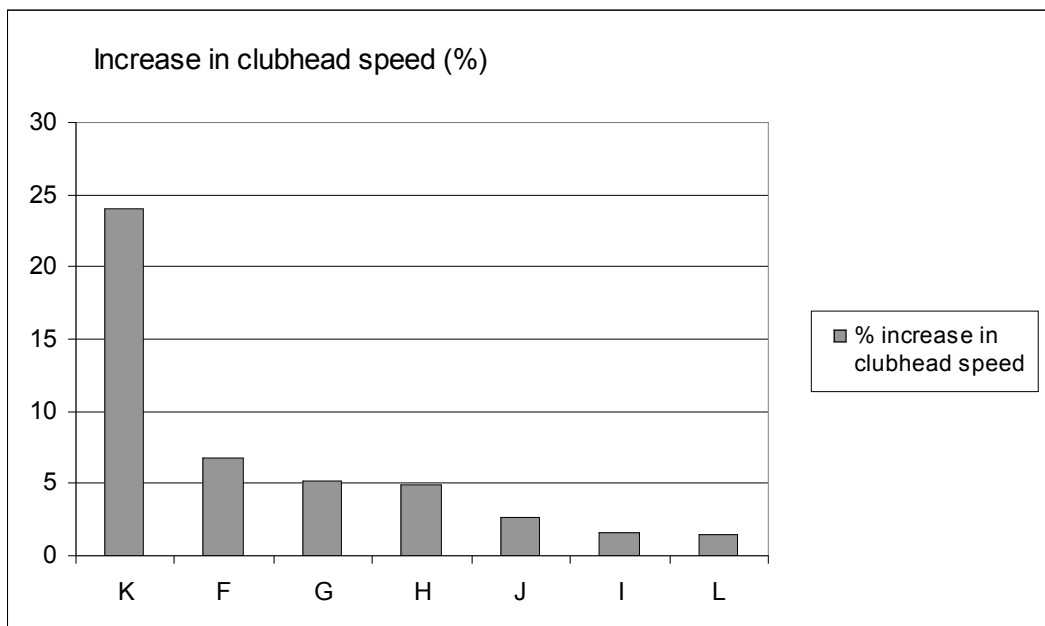
flexibility, muscular strength, balance and cardiovascular performance (Table 5). None of the studies have included or measured muscular endurance as part of the intervention.

In regards to flexibility, torso rotation has improved significantly after all training interventions, which have exercises for this as part of the program (F, G, I, J). Other significant improvements include flexibility of the shoulders, neck, chest and hip.

When it comes to muscular strength, significant improvements in overall lower body- and upper body strength are reported (H, I, J), and the same goes for torso rotation strength (G), and total body rotational power (I).

The two studies measuring balance both show significant improvements, one for static balance (G) and one for dynamic balance (H). One study shows significant improvements in cardiovascular performance (H). Aerobic exercise was included in this training intervention as a five minute warm up.

All physical training interventions show significant improvements of golf performance in terms of increased clubhead speed, ranging from an increase of 1,5% to 24% (Figure 5). The study showing a 24% increase (K) differs from the other studies in the sense that it didn't allow for any warm up prior to the first measurement of clubhead speed. Three of the studies measure driving/total distance and all show significant improvements; between 4,3% and 7,9% (F, G, L). One study looks at ball speed and carry distance, reporting significant improvements for both of them (G) (Table 5).



**Figure 5.** Increase in clubhead speed (%) after the training interventions

**Table 5. Significant effects of physical training interventions**

Article	Significantly improved physical fitness characteristics <sup>1</sup>				Significantly improved golf performance <sup>1</sup>
	Flexibility	Muscular strength	Balance	Cardiovascular performance	
F	YES Torso rotation Pectoralis major Neck muscles	NM <sup>3</sup>	NM	NM	YES  CHS: +6,8% DD: +7,9%
G	YES Torso rotation Shoulder rotation Hip abduction/ adduction	YES Torso rotation Hip abduction	YES Static	NM	YES  CHS: +5,2% BS: +5% CD: +7,7% DD: +6,8%
H <sup>2</sup>	YES Lower body	YES Lower body	YES Dynamic	YES	YES  CHS: +4,9%
I	YES Torso rotation	YES Total body rotational power Lower body Upper body	NM	NM	YES  CHS: +1,6%
J <sup>2</sup>	YES Torso rotation Torso lat. flexion Shoulder rotation Shoulder abduction	YES Lower body Upper body	NM	NM	YES  CHS: +2,7%
K <sup>2</sup>	NM <sup>3</sup>	NM	NM	NM	YES  CHS: +24%
L <sup>2</sup>	NM <sup>3</sup>	NM <sup>3</sup>	NM	NM	YES  CHS: +1,5% DD: +4,3%

<sup>1</sup> Or significantly better than control group

<sup>2</sup> Randomized Controlled Study

NM = Not measured

NM<sup>3</sup> = Not measured, but part of training intervention

CHS = Clubhead speed

DD = Driving/total distance

BS = Ball speed

CD = Carry distance

## 4. Discussion

### 4.1 Method/material discussion

The method chosen for this thesis was a literature review. During the project phase, initial searches indicated that there wasn't extensive research in this area. Therefore, to avoid the risk of missing relevant articles, the inclusion criteria specified for the searches were kept to language (Swedish or English) and time frame. The search period included the past five years to start with. To ensure a sufficient number of articles, the search period was extended to include the past seven years. The final selection of articles included only original publications.

Looking at the selected articles they vary slightly in terms of perspective:

- Some articles focus only on physical fitness characteristics and their correlation to golf performance (Basically: *“Is there a difference in physical fitness characteristics between golfers performing at different skill levels?”*)
- Some articles focus only on physical training interventions and their effect on golf performance (Basically: *“Does physical training improve golf performance?”*), and
- Some articles study physical training interventions, as well as physical fitness characteristics in relation to golf performance (Basically: *“Does physical training improve physical fitness characteristics as well as golf performance?”*).

Another strategy for selecting articles could have been to focus on only one of the above. For example to include only articles that look at the effects of physical training interventions on golf performance. Extending the time frame with a few more years, to include the past ten or fifteen years, might have resulted in a sufficient number of such articles. This approach would have facilitated the review process, and perhaps would have made the result more easily accessible to the reader. However, including all perspectives outlined above, and limiting the time frame to the past seven years, allowed for a big picture view of the most current research within the field of physical fitness and golf performance.

The searches were made in four databases; PubMed, Cinahl, AMED and PEDro. Not using additional databases may have limited the number of relevant articles found. Seven search terms were used, including different perspectives of physical fitness and golf performance. The number of hits and the number of relevant articles found, as presented in Tables 1 and 2, reflect that a lot of research hasn't been made.

Four of the twelve selected articles are randomized controlled studies (H, J, K, L). This may seem little at first sight. However, for five of the remaining eight articles a randomized controlled study does not apply. They don't study the results of an intervention, but study the current fitness characteristics of golfers at different skill levels. Also, in the articles that compare low and high hcp golfers, the high hcp groups of golfers tend to function as control groups.

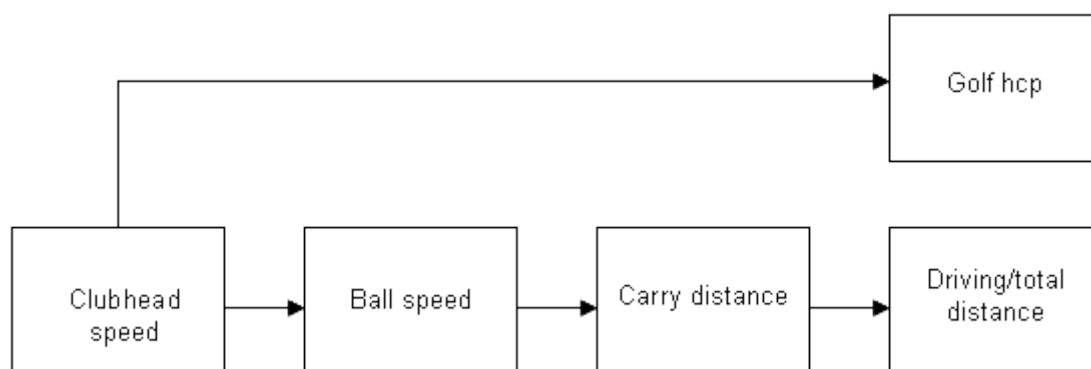
The somewhat heterogeneous character of the selected articles limits the possibility to compare the results and draw conclusions based on such comparisons. At the same time, it has not been the main purpose of this literature review to allow for such comparisons – but rather to provide an overall understanding of the current knowledge in this field.

### 4.2 Result discussion

The purpose of this study was to explore what research has said about the link between physical fitness and golf performance.

Several different measures of golf performance are used in the articles (Figure 3). However, it's important to note that many of them are correlated (Figure 6). Also, nearly all studies use clubhead speed as a measure. The remaining three studies (C, D, E) use measures that are either directly influenced by, or correlated to clubhead speed.

As addressed in the background chapter, golf performance can be influenced by several factors. Depending on which golf performance measure you study, physical fitness may be one of many influencing parameters, or it may be one of a few key influencers. Clubhead speed is an example of the latter, and from the articles reviewed here, researchers seem to be in alignment with the view that clubhead speed is the preferred measure of golf performance in relation to physical fitness characteristics or physical training.



**Figure 6.** Correlations between golf performance measures

[Based on information in A, B, D, I, 7 and 8] The model does not intend to give a complete picture of all elements influencing golf hcp or driving/total distance. Instead, its purpose is to provide an overview of correlations between some of the golf performance measures used in the articles included in this literature review.

#### *Physical fitness characteristics studied*

All articles, except two, study and evaluate physical fitness characteristics. Flexibility, muscular strength, and balance/stability are most frequently studied – and this makes sense when thinking of the demands of the golf swing. Cardiovascular performance, evaluated in a couple of articles, may not be as relevant when using golf performance measures such as clubhead speed. But, if looking at golf scores, or even golf hcp, this may have a more important role. Playing a round of 18 holes and walking the course requires some aerobic capacity – even if the cardiorespiratory challenges of golf are not considered intense. Research has shown an exercise intensity ranging from 52,1% to 78,7% of maximal heart rate, although the higher number relate to three selected holes on a hilly course [4].

There are some variations between the articles when it comes to the specific characteristics studied within the different fitness areas. It's interesting to note that only three studies have measured a golf swing specific fitness characteristic; that of total body rotational power. Evaluating a movement that is specific to the golf swing, compared to not doing this, may affect results.

#### *Physical training interventions studied*

The physical training interventions differ in many ways, for example in terms of specific exercises, number of sets and repetitions, and duration of each session. However, the interventions also have common denominators, including the fact that all of them are overall body conditioning programs. It's also worth noting that a majority of the interventions include

total body rotational power exercises, mimicking the golf swing. Sport specific training activities, such as that of mimicking the movement of the golf swing, is generally thought to create specific training results, referred to as the specificity principle [10].

When it comes to torso rotation, scientific studies have shown that it's the ability to separate the torso and pelvis, rather than creating maximal torso and pelvis rotation, that is most important to obtain higher golf ball speed [8, 11]. Based on this, it would be beneficial to include exercises that allow participants to practice this separation specifically. Total body rotational exercises don't ensure this. In reviewing the specific exercises for torso rotation, included in the interventions, it's not evident that they allow for practicing the active separation between torso and pelvis.

### *Significant correlations*

Although significant correlations are found between all areas of physical fitness characteristics and golf performance, the picture is not clear. In most cases there is only one study supporting a significant correlation. The results between studies are sometimes also inconsistent, with one study showing a significant correlation whereas another doesn't.

Of as much interest as the significant correlations found, are also the significant correlations not found. Some articles discuss these as well, whereas some don't. By comparing the correlations studied, with the results presented, one can find non-significant correlations such as hamstring flexibility and golf hcp (D), torso flexibility and clubhead speed (B), peripheral muscle strength and clubhead speed (A, I), and shoulder strength and clubhead speed (I). In one article the whole study focuses on dynamic balance and golf hcp, but the authors find no significant correlation. This article is the only one, of the twelve included in this review, that doesn't show a positive link between physical fitness and golf performance (E).

A number of factors may contribute to these scattered results:

- Only six articles have studied correlations, and there are not many of these articles that look at exactly the same correlations.
- In some studies, there are not enough participants to allow for correlations to reach significance.
- In the articles that compare low and high hcp golfers, the differences in golf hcp in these specific cases might relate more to swing technique than to physical fitness characteristics.
- The evaluation methods differ between several of the studies.

One significant correlation stands out, though, being supported by three different studies. It's that of total body rotational power and clubhead speed or golf hcp. This is not surprising, considering the specificity principle mentioned above. It fits well with the clinical perspective: During the downswing, in the acceleration phase, the ability to quickly rotate the torso is a key element [3]. In scientific research, upper torso rotation velocity has also shown to be the most important predictor at acceleration [8].

As mentioned in one of the articles, it's important to note that correlations should be interpreted with caution, since they don't imply causality. Rather, they should be used for general understanding of relationships between variables (C).

### *Significant effects of physical training*

Regarding effects of the physical training interventions, the picture is clearer. All training interventions significantly improve golf performance as well as physical fitness characteristics

(when measured). Considering the significant correlation found between total body rotational power and golf performance, discussed above, it's of interest to note that torso rotation, both in terms of flexibility and strength, improved through several training interventions – as did clubhead speed.

To allow for high torso rotational speed in the golf swing, it's important with lower body strength and stability [3]. Several of the training interventions show significant improvements in these areas as well.

When it comes to muscular strength, it has been discussed if muscular hypertrophy could limit range of motion and thus have a negative effect on golf performance. The optimal degree of muscular hypertrophy for golf is not known (A). This review doesn't show signs of increased muscular strength negatively influencing golf performance. However, most training interventions lasted no more than eight weeks. In this period, strength training results in neuromuscular effects rather than hypertrophy [12]. Further studies could focus on the long-term effects of strength training in relation to golf performance.

The large increase in clubhead speed of 24%, obtained through one of the training interventions (K), likely depends on the fact that they didn't allow for any warm up before the first measurement of clubhead speed. This highlights the issue of what can be done with statistics – how a number or graph (like Figure 5) can send misleading messages to the reader if the underlying data is not analyzed further. In this case, the method of measuring clubhead speed before warm up the first time, after warm up the second time and after a five week warm up conditioning program the last time, led to another interesting result, though: Even a short warm up prior to play can make a difference to golf performance.

Finally, it's important to consider that the participants of the different studies included in this review differ quite a lot in terms of for example age and golf hcp (see Appendix 1). The evaluation methods also differ, further limiting the possibility to compare results. In regards to reliability and validity of the evaluation methods there is often limited information. Several articles refer to reliability shown in their own laboratories. Only two of the studies include women, with one of them highlighting differences in results between sexes. This is an area for further exploration in future research. It would also be interesting to compare two different modes of training interventions, for example a gym based program and a body/mind training intervention like basic body awareness or yoga. Other areas of interest for further investigation include the long-term effects of strength training on golf performance as mentioned above, as well as the relation between physical training, swing technique and golf performance.

### **4.3 Conclusion**

Eleven of 12 articles show a positive link between physical fitness and golf performance, highlighting the importance of flexibility, strength and core stability. However, differences in study participants, evaluation methods and training interventions indicate the need for further studies in this field.

### **4.4 Clinical implications**

Although, there is not sufficient data to support specific recommendations when it comes to physical training in relation to golf performance, the results presented in this review can work as guidelines for physiotherapists helping people get fit for golf.



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## Appendix 1

*Study participants – an overview.*

Article	Number of participants	Sex	Age	Golf hcp
A	20	Male	22,9 +/- 3,4 (low hcp) 27,8 +/- 7,8 (high hcp)	0,3 +/- 0,5 (low hcp) 20,3 +/- 2,4 (high hcp)
B	15	Male	34,3 +/- 13,6	4,9 +/- 2,9
C	24	Female: 9 Male: 15	22,1 +/- 6,6 23,2 +/- 3,2	Best amateur golfers in Canada (elite)
D	257	Male	45,5 +/- 12,8	< 0 (+2,0 +/- 2,3) 0-9 (4,5 +/- 2,4) 10-20 (13,7 +/- 2,9)
E	52	Male	18-55	0-9 10-16 17+
F	1	Male	19	<10
G	15	Male	47,2 +/- 11,4	12,1 +/- 6,4
H	18 (of which 7 in control group)	Male	70,7 +/- 9,1	Not included
I	16	Female: 6 Male: 10	18,5 +/- 0,8 (women) 19,8 +/- 1,7 (men)	5-10 (women) 0 (men)
J	31 (of which 12 in control group)	Male	55-79	All hcp levels
K	20 (of which 10 in control group)	Male	23-64	12-27
L	11 (of which 5 in control group)	Male	29 +/- 7,4	5,5 +/- 3,7