Katholieke

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GROEP BIOMEDISCHE WETENSCHAPPEN

Faculteit Lichamelijke Opvoeding
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The external rotation : internal rotation strength ratio

for swimmers with shoulder complaints

door **Jacqueline Stoel**

Thesis aangeboden tot het behalen van
de graad Master in Physiotherapy

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Samenvatting

Titel: The external rotation : internal rotation strenght ratio for swimmers with shoulder complaints

Auteur: Jacqueline Stoel

Promotor: Prof. Dr. Marc Van Leemputte

Copromotor: Dr. Hugo Moolenaar

De ‘zwemmersschouder’ is een frequent voorkomende blessure bij zwemmers. Impingement, instabiliteit en musculaire dysbalans worden als ontstaansmechanismen genoemd. Doel van deze studie is om bij zwemmers met schouderklachten de vermoeidheidsratio van de schouder-rotatoren te onderzoeken, en om een inzicht te verkrijgen in de isokinetische referentie-waarden voor exo- en endorotatie van de schouder. De metingen zijn uitgevoerd op de Biodex multi-joint system (control model 900-350, Biodex medical systems, Inc., Shirley, New York) en de betrouwbaarheid van het isokinetische schouder testprotocol is onderzocht in een pilot-studie met 20 studenten. De isokinetische schoudertest voor exo- en endorotatie is uitgevoerd in een liggende positie op de buik, met testsnelheden 180°/sec en 240°/sec voor respectieve-lijk vijf en dertig testherhalingen door dertig Nederlandse zwemmers. De vermoeidheidsratio wordt berekend met de gemiddelde peak torque voor exo- en endorotatie en wordt op twee manieren geanalyseerd: 1) zwemmers met schouder schouderklachten worden vergeleken met zwemmers zonder schouderklachten, en 2) de aangedane zijde wordt vergeleken met de niet-aangedane zijde bij mannelijke zwemmers met schouderklachten. In de statistische analyse zijn onafhankelijke en afhankelijke t-toetsen gebruikt. Voor de mannelijke zwemmers met schouderklachten is er een significante verschil ($p < .05$) tussen de aangedane en niet-aangedane zijde voor de vermoeidheidsratio exorotatie. Dit betekent dat de exorotatoren minder weerstand kunnen bieden tegen vermoeidheid dan de endorotatoren, wat zou kunnen resulteren in een musculaire dysbalans van de schouder.

Voorwoord

Deze verhandeling wordt aangeboden in de vorm van een wetenschappelijk artikel voor het behalen van de graad ‘Master in Physiotherapy of Science’ aan de Faculteit Lichamelijke Opvoeding en Kinesitherapie van de Katholieke Universiteit Leuven. Hierbij is rekening gehouden met de tot nu toe beschreven richtlijnen waaraan een verhandeling in de vorm van een wetenschappelijk artikel dient te voldoen.
Voor het tot stand komen van deze verhandeling zou ik mijn promotor, Prof. Dr. Van Leemputte willen bedanken voor de prettige samenwerking, zijn adviezen en commentaar. Daarnaast wil ik mijn copromotor, Dr. Hugo Moolenaar bedanken voor zijn enthousiasme, interesse, steun en raad op het inhoudelijk vlak. Verder dank ik M.Sc. Pt Geert Aufdemkampe voor zijn steun op het statistische en inhoudelijke vlak. Naast deze personen dank ik alle anderen die de tekst van deze verhandeling hebben gelezen en taalkundig hebben gecorrigeerd. Als laatste wil ik mijn familie en vrienden bedanken voor hun hulp bij de verwerking van de gegevens en hun steun op het mentale vlak.
Dankzij het in bruikleen stellen van de Biodex Dynamometer door Jan-Willem Lutjenkossink in zijn praktijk voor fysiotherapie te Woudenberg, Nederland, kon dit onderzoek uitgevoerd worden. Door de hulp van Françoise van Sliedrecht, fysiotherapeut, bij het testen kon het onderzoek in een tijdsbestek van drie maanden praktisch worden afgerond. Dankzij de computer technische ondersteuning van Bertwin Oudenampsen zijn er tijdens het millennium géén data verloren gegaan en is alles zonder problemen verlopen.
Tenslotte ben ik zeer veel dank verschuldigd aan alle studenten en zwemmers die hebben deelgenomen aan het onderzoek.

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Situering

Deze studie is uitgevoerd in het kader van de opleiding Master of Physiotherapy en heeft als onderwerp ‘schouderklachten bij zwemmers’. In de literatuur wordt de blessure ook wel ‘zwemmersschouder’ genoemd. Interesse in dit onderwerp is ontstaan daar ik zelf als wedstrijdzwemmer deze typische schouderblessure heb ervaren. Ten tweede kreeg ik door contacten met zwemmers en mijn beroep als fysiotherapeut steeds meer te maken met schouderblessures bij zwemmers. Als fysiotherapeut ben ik me gaan verdiepen in de oorzakelijke factoren en behandelbare grootheden van de zwemmersschouder.

Tijdens het zwemmen wordt vooral kracht geleverd tijdens de doorhaal van de zwembeweging met de endorotatoren en adductoren van de schouder (Scovazzo, Browne, Pink, Jobe & Kerrigan, 1991). Bij de overhaal van de zwembeweging zijn de exorotatoren en abductoren (Scovazzo, Browne, Pink, Jobe & Kerrigan, 1991) van de schouder actief. De weerstand van het water is groter dan van de lucht, waardoor endorotatoren en adductoren relatief meer arbeid moeten verrichten gedurende de zwembeweging. Mijns inziens kan de eenzijdige en cyclische zwembeweging bijdragen tot de ontwikkeling van een musculaire dysbalans rond het schoudergewricht. Welke vervolgens secundair impingement kan veroorzaken. Indien er sprake is van een musculaire dysbalans van de schouder bij zwemmers met schouderklachten, dan kan dat als aangrijpingspunt in de therapie dienen. Uiteindelijk kan men zich afvragen of een stukje preventieve oefentherapie bijdraagt tot blessurepreventie van de schouder bij de wedstrijdzwemmer.

In deze studie is de fysieke belasting van een Nederlandse zwemmer geïnventariseerd en is de theorie van de musculaire dysbalans aangegrepen, om nader te onderzoeken. Voor een goede inventarisatie van lokale en algemene belasting van de zwemmer is een zelf ontwikkelde specifieke vragenlijst (appendix B) gebruikt. De resultaten van deze lijst worden gepresenteerd in appendix C. Om de theorie van de musculaire dysbalans te kunnen onderzoeken, is gebruik gemaakt van een isokinetisch schoudertest voor exo- en endorotatie op een Biodex dynamometer. Met een isokinetisch meetinstrument meet men momenten (moment (Nm) = kracht (N) x afstand (m)) in een dynamische toestand. Bij een isokinetische test contraheert een spiergroep tegen een gecontroleerde accomoderende weerstand, die wordt bewogen met een constante hoeksnelheid (Dvir, 1995). Het maximale moment in de geteste beweging heet de ‘peak torque’ en wordt weergegeven in Newton-meter (Cingel, Aufdemkampe & Bois, 1995). De peak torque is in deze studie gebruikt om andere parameters te definiëren.

Bij de verwerking van de data bleken vooral de definitie van de ratio en de grote hoeveelheid data voor problemen te zorgen. In het artikel is daarom gekozen voor het weergeven van een beperkte hoeveelheid data. Als definitie voor de te toetsen ratio is gekozen voor een vermoeidheidsratio (fatigue ratio). Hiermee wordt de weerstand, die door de exo- en endorotatoren kan worden geboden, tegen vermoeidheid weergegeven. De vragenlijst is gebruikt als selectie criterium om te bepalen of een zwemmer behoort tot de groep met of zonder schouderklachten. Mijns inziens heeft de selectie van resultaten uit deze studie bijgedragen tot een klinisch relevant artikel voor de fysiotherapeut, zwemcoach, zwemmer en andere geïnteresseerden.

The external rotation : internal rotation strength ratio for swimmers with shoulder complaints.

J.M. Stoel, H. Moolenaar, M. Van Leemputte

Keywords: swimmers shoulder, isokinetics, fatigue ratio, muscular imbalance

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Jacqueline, JM Stoel, PT, was a student at the University of Leuven at the time this research was completed in fullfillment of the requirements for her Master of Science degree in Physical Therapy. She is currently physical therapist at the physical therapy practice Lutjenkossink, Geeresteinselaan 26, 3931 JC Woudenberg, The Netherlands
(jstoeltje@hotmail.com), adress all correspondence to Mrs Stoel

Hugo Moolenaar, Ph.D. Pt., Hogeschool van Utrecht, Department of Physical Therapy, The Netherlands

Marc Van Leemputte, PhD, Professor of Biomechanics, Katholieke Universiteit Leuven, Faculty of Physical Education and Physical Therapy, Exercise Physiology and Biomechanics Lab, Leuven, Belgium

This study was performed at physical therapy practice Lutjenkossink, Woudenberg, The Netherlands

Abstract

A common injury in swimming is the “swimmer’s shoulder”. Purpose of this study is to examine shoulder rotators muscle fatigue ratio (FR), and provide isokinetic reference values for shoulder external and internal rotation in swimmers with shoulder complaints. Measurements are executed on the Biodex multi-joint system (control model 900-350, Biodex medical systems, Inc., Shirley, New York) and repeatability for the isokinetic shoulder test protocol is calculated in a pilot-study with twenty students. Thirty Dutch swimmers completed the isokinetic shoulder test for external and internal rotation, in prone position, at testing-speeds 180 and 240 deg/sec for respectively five and thirty repetitions. FR is analysed in two ways: 1) swimmers with shoulder complaints are compared with swimmers without shoulder complaints, and 2) the involved side is compared with the uninvolved side for male swimmers with shoulder complaints. FR is computed with mean peak torque for external and internal rotation and analysed statistical with dependent and independent t-tests. Significant difference ($p < .05$) existed between the involved and non-involved side for FR external rotation in male swimmers with shoulder complaints. This means less fatigue resistance of external rotators than internal rotators, which could result in muscular imbalance and secondary impingement of the shoulder.

Introduction

Swimming has a relatively low risk of injury (Fowler & Forwell, 1999). However, the intensely repetitive nature of the sport, particularly at the elite level, can result in overuse problems in shoulder, elbow, knee, foot, ankle, and back (Fowler & Forwell, 1999; Kenal & Knapp, 1996). Shoulder injury is the most common problem facing the competitive swimmer (Johnson, Sim & Scott, 1987; Fowler & Forwell, 1999; Allegrucci, Whitney & Irrgang, 1994). In a study of McMaster & Troup (1993) 1262 United States swimmers of different ages were questioned about the incidence of shoulder complaints. McMaster & Troup reported a current incidence of shoulder complaints of 10 % in junior swimmers to 26 % in the elite swimmers, and a history of pain in junior swimmers of 47 % and 73 % for the elite swimmers. Decrease in these high percentages should be wishful because up to 90% of the propulsion with swimming is generated from the arm pull (Johnson et al., 1987).

Three common etiologies of shoulder pain are shoulder impingement, instability and muscular imbalance (Kamkar, Irrgang & Whitney, 1993; Rupp, Berninger & Hopf, 1995; Bak & Magnusson, 1997). Researchers have stated that the primary cause of shoulder pain in swimmers is impingement of the rotator cuff, biceps caput longum tendon, subdeltoid bursa, and subacromial bursa under the coracoacromial arch (Beach, Whitney & Dickoff-Hoffman, 1992). The mechanism of injury is believed to be the result of repetitive stress, overuse, and improper stroke mechanics and is usually not suddenly traumatic (Beach et al., 1992; Fowler & Forwell, 1999). The factor overuse could simply be demonstrated with an example: if the average swimmer swims 10000 metres daily, estimating ten cycles for every twenty-five metres, there would be 4000 repetitions per shoulder on daily basis (Allegrucci et al., 1994). After prolonged use, in a swimming practice, of the rotator cuff and scapular stabilisers a muscular fatigue could lead to increased anterior and superior humeral head translation, poor stroke mechanics and eventually to secondary impingement (Allegrucci et al., 1994; Murphy, 1994). Shoulder pain in swimmers is usually due to tendinitis of the m. supraspinatus and m. biceps brachii caput longum (Johnson et al, 1987; Murphy, 1994; Kenal & Knapp, 1996). Therefore, the first aim of the study is to investigate muscle fatigue of external and internal rotators of the shoulder for swimmers with shoulder complaints. Second aim is to provide normative values of peak torque and endurance ratios (ER/IR) for external and internal rotation in competitive swimmers. An isokinetic shoulder test for external and internal rotation is used to achieve these goals. The null hypothesis in this study states no significant difference of shoulder external and internal rotator muscle fatigue ratio and mean peak torque for swimmers with shoulder complaints. Hypothesis testing is executed in two ways. First swimmers with shoulder complaints are compared to swimmers without shoulder complaints (between-group analysis). Second the injured shoulder is compared with the non-injured shoulder for swimmers with shoulder complaints (side-to-side analysis). This will enable greater understanding of muscle fatigue in rotator cuff muscles for swimmers with shoulder pathology and may be helpful to make a specific rehabilitation program for swimmers with shoulder complaints.

Method

Design

The research protocol consists of two parts and is approved by the Independent Review Board (Amsterdam, The Netherlands, 1999). All participants in the study signed a written informed consent. Participants with age sixteen or seventeen also need permission of their parents. First a pilot-study is executed to get practical experience in isokinetic shoulder testing and calculate repeatability for the isokinetic shoulder test protocol. Second part of the research protocol contains a questionnaire and isokinetic shoulder test[1] for swimmers. The questionnaire is used to gain an insight into the constitution of the research population and is used as selection criterion. The isokinetic shoulder test was used to measure muscle fatigue ratios for internal and external rotation of the shoulder and performed on the Biodex multi-joint system (control model 900-350, Biodex medical systems Inc., Shirley, New York). Peak torque[2] is used to define the parameters and ratios (table 1).

Procedure

Twenty students have participated voluntarily in the pilot-study. All invited students were included in the study for the isokinetic shoulder test. Subjects were tested bilaterally at the Biodex dynamometer for shoulder external and internal rotation. Seven days following the initial test a retest was administered using the identical protocol. After completion of the pilot-study the second part of the research protocol could be started.

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[1]The isokinetic shoulder test is executed at physical therapy practice Lutjenkossink in Woudenberg, The Netherlands.
[2]Peak torque is the highest value of torque development throughout the range of motion. Torque is a function of force and distance from the axis of rotation as measured by the Biodex dynamometer.

Four different Dutch swimming clubs[3] are invited to participate in this study. After permission of the club-trainer to participate in the study, seventy swimmers have received an information letter, written informed consent, and questionnaire. Forty-six swimmers filled in the questionnaire. To be included in the study the swimmer must have the minimum age of sixteen and needs to swim in the highest division of the Dutch swimming competition. All swimmers (N=46) are invited for the isokinetic shoulder test as nobody has a history of shoulder surgery, shoulder dislocation or played more than two times a week another overhead sport (water polo, tennis, baseball and volleyball). Finally, thirty swimmers have voluntarily completed the isokinetic shoulder test. Dropout reasons for the shoulder test were fear of shoulder injuries and therefore missing Dutch championships or the Olympic Games, and fear of a longer rehabilitation time for an existing shoulder injury.

The researcher used two methods for the between-group analysis to decide whether the swimmer belonged to the group with or without shoulder complaints. First the answers to the questions about shoulder complaints in the questionnaire. Second the answers at the anamnesis prior to the shoulder test. The anamnesis is especially used to provide status praesens about shoulder complaints of the subjects. Admission of a swimmer into the group with shoulder complaints was depending on three selection criteria:

1. Shoulder complaints in the last year before the study (December 1998 till December 1999).
2. Shoulder complaints at the beginning, during or after a swimming session.
3. No trauma in the anamnesis of the involved shoulder.

Selection criteria one is based on the normal turnover of collagen type I, which is 300-500 days. Normal recovery of the injured tissue takes at least one year (Van Wingerden, 1997). Every swimmer was tested with the same standardised test protocol.

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[3] The clubs are: AZ&PC, DWK, De Haaien, and Aquarijn.

Protocol

All choices concerning the test protocol were based as much as possible on functionality for swimmers. The checklist of Keating & Matyas (1996) about reporting an isokinetic test protocol was used to give an extensive description of the isokinetic shoulder test protocol. Measurements were executed on the Biodex multi-joint system for external and internal rotation of the shoulder joint. The Biodex was calibrated according to the manufacturer's specifications before testing. Personal data for each subject included age, hand dominance, weight, and length. Those data were put into the Biodex computer (advantage software V3.0.3., Biodex medical systems Inc., Shirley, New York). Before testing subjects started a warming-up of fifteen minutes. Consisting of ten minutes on the home-trainer and five minutes on the arm-bike (UBXT, Technogym, Italy). Following the warming-up the swimmer received a brief instruction about the test procedure. The subject was instructed to move his shoulder as fast and hard as possible during the isokinetic shoulder test. Each isokinetic shoulder test was performed bilaterally. In case the swimmer has shoulder complaints the first arm to be tested was the uninvolved. The first arm to be tested in swimmers without shoulder complaints was decided with a coin toss.

To measure external and internal rotation the subjects were positioned prone on a testing table with their head down in the hole of the testing table. The prone position is functional to swimmers because freestyle, breaststroke and butterfly stroke are in prone position (Beach et al., 1992). One or two pillows of one cm were placed under the shoulder to prevent shoulder pronation during testing. A strap was used to stabilise the chest on the testing table. The head of the Biodex dynamometer is positioned at 87 cm, measured from the ground till the axis of rotation.

After that the horizontal (0º) was measured with a level. The end range external rotation was set at 20º and end range internal rotation at 80º. Total range of motion was 60°. According to the manufacturer's specifications the sensitivity was set at 'C' and the cushion was set at hard. The shoulder and elbow were in 90º abduction and flexion. The forearm was in pronation and was stabilised with a strap at the lever arm just below the elbow. Then the lever arm length was adapted to the length of the subject's forearm. After this the testing table was installed at proper height and the olecranon of the ulna was used as line of sight for axis alignment. All measures were corrected for gravity because internal rotators were assisted by gravity whereas the opposite is true for external rotators (Dvir, 1995). Limb weight was measured in end range external rotation because gravitational forces are the greatest in that position. Isokinetic external and internal rotation strength was measured at speeds 180°/sec and 240°/sec. Beach et al. (1992) mentioned 240°/sec a sport-specific speed, calculated with number of arm strokes per 25 yards and the average time over 25 yards. Three submaximal repetitions and two maximal repetitions per test speed were used as specific warming-up prior to testing. Before the test began a 30-second rest followed after the practice repetitions. The test included five repetitions at 180°/sec and 30 repetitions at 240°/sec, with one-minute rest between the two test speeds. During the test the subject was encouraged with the verbal commands: "high-low". After completion of the test at one side the subject was given a five-minute rest. In that period the test instructor prepared the computer and Biodex for the test of the other side. At the end a comprehensive report was printed.

Parameters

In this study the variables peak torque and endurance ratios 240°/sec. (ER/IR) were only used to provide reference values. Mean peak torque and muscle fatigue ratio (FR) were used as variables in hypothesis testing and only calculated for 240°/sec. Actually FR means the capacity of a muscle group to resist fatigue, fatigue resistance, when it is performing repetitive movements.

Beach et al. (1992) named fatigue ratios in their study endurance ratios and calculated them by dividing the mean peak torque of the last three repetitions by the first three repetitions multiplied by 100. In this study same calculation was used but the mean peak torque was calculated for five repetitions. Mean peak torque for five repetitions gives a more representative measure because the mean is based on more peak torque values.

Peak torque means were calculated for the first and the last five repetitions of external and internal rotation. FR is calculated by dividing the mean peak torque of the first five repetitions by the mean peak torque of the last five repetitions multiplied by 100. In the data analysis two different FR were tested for differences. First the FR external rotation (FR-ER) and second the FR internal rotation (FR-IR). Endurance ratios (ER/IR) were calculated by dividing the mean peak torque external rotation by the mean peak torque internal rotation. This results in four different ER/IR ratios. Expression of the peak torque means, FR, and ER/IR are summarised in table 1.

With the option analyse test curves in the Biodex computer, subjects test results were analysed and the muscle fatigue ratios were calculated. First the researcher selected the set for the uninvolved side at 240°/sec and windowed the data. The peak torque for external and internal rotation from the first and the last five repetitions were read off the computer. After that mean peak torque values, FR and ER/IR ratios were calculated. Same procedure was used for the involved side.

Statistical analysis

Data of the pilot-study were used to calculate the Intraclass Correlation Coefficient (ICC). The ICC classification model (3,1) of Shrout & Fleiss (Portney & Watkins, 1993) was used to test repeatability of the isokinetic shoulder test protocol.

Descriptive statistics for the swimmers and the reference values are presented as means and 95% confidence interval (95% CI). The muscle fatigue ratios are expressed as percentages. The Kolmogorov-Smirnov test was used to test whether the data were normally distributed. Dependent (side-to-side comparison) and independent (between-group comparison) t-tests were used to establish differences for muscle fatigue ratios and mean peak torque values. In all comparisons an alpha level of .05 was used. The SPSS 8.0 analysis package was used to perform all statistical analyses.

Results

Twenty students (male=9, female=11, mean age=22,60 ± 1,64, mean weight= 69,74 ± 8,85, mean height=175,83 ± 6,79) completed the isokinetic shoulder test two times with a rest period of one week. The ICC (3,1) calculated for peak torque ranged from .64 to .87, coefficients for mean peak torque ranged from .69 to .91, and for muscle fatigue ratio ICC ranged from .15 to .92.

Second part of the statistical analysis was started with the Kolmogorv-Smirnov test. According to the Kolmogorov-Smirnov test data were normally distributed. Therefore, parametric statistics were used for hypothesis testing. Reference values about all swimmers are summarised in table 2 and 3. Results of the independent t-test showed non-significant differences ($p > .05$) between swimmers with and without shoulder complaints for fatigue ratio and mean peak torque.

Reference values about male swimmers with shoulder complaints are summarised in table 4. The dependent t-tests showed significant and non-significant results for male swimmers with shoulder complaints between the involved and uninvolved shoulder (table 5). A non-significant difference ($p > .05$) existed between ER1 & ER3, IR1 & IR3, IR2 & IR4, and for FR-IR. Significant difference ($p < .05$) existed between ER2 & ER4, and for FR-ER. At the uninvolved side the mean FR-ER was 86 % and at the involved side it was 79 %. Those significant differences are especially due to significant decrease in mean peak torque external rotation for the last five repetitions. The mean peak torque external rotation for the last five repetitions at the uninvolved side was 29,3 Nm and 26,1 Nm at the involved side.

Discussion

Many studies (Allegrucci et al., 1994; Bak & Faunø, 1997; Johnson et al., 1987; McMaster & Troup, 1993; Kamkar et al., 1993; Kenal & Knapp, 1996; Russ, 1998; Beach et al., 1992; Rupp et al., 1995; McMaster, Long & Caiozzo, 1992; Bak & Magnusson, 1997; Scovazzo, Browne, Pink, Jobe & Kerrigan, 1991; Pink, Perry, Browne, Scovazzo & Kerrigan, 1991; Yanai & Hay, 2000) were aimed to give better understanding in 'swimmers shoulder', and to prove differences between swimmers with or without shoulder complaints in order to find causative factors. In our study we tried to find a causative factor which could be a point of impact in rehabilitation. Therefore, we choose to examine the theory of the muscular imbalance with an isokinetic shoulder test for external and internal rotation.

Before the research started, repeatability for a measurement must be satisfied in order to be meaningful and interpretable (Dvir, 1995). Frisiello, Gazaille, O'Halloran, Palmer & Waugh (1994) were the only researchers who performed a shoulder test-retest study with the Biodex dynamometer. The shoulder was tested bilaterally at 90°/sec and 120°/sec for eccentric shoulder external and internal rotation. Results of the study showed that the ICC ranged from .73 to .86. Frisiello et al. (1994) concluded the eccentric mode for shoulder external and internal rotation to be reliable for the test-retest measure of peak torque. In this study subjects were tested concentric with a different isokinetic shoulder test protocol. Therefore, we performed a pilot-study to calculate the ICC for this isokinetic shoulder test protocol. The repeatability coefficients are interpreted on the basis of their proximity to a value of 1.00 (Portney & Watkins, 1993). Portney & Watkins indicate as a general guideline, coefficients lower than .50 as poor repeatability, coefficients from .50 to .75 as moderate repeatability and values above .75 as good repeatability. According to those general guidelines repeatability in this study for concentric external and internal rotation of the shoulder was moderate or good reliable for the parameters peak torque and mean peak torque, and for the parameter FR it was poor, moderate or good reliable. The results in this study should be interpreted with these ICC values in mind.

Reference values of peak torque and ER/IR ratios in this study were difficult to compare with the results of other studies because isokinetic shoulder testing is still not standardised. In isokinetic literature the shoulder joint is tested in many different positions (Dvir, 1995). Every study uses a different standardised isokinetic shoulder test protocol and has its own advantages and disadvantages (Cingel, Aufdemkampe & Bois, 1997). In the majority of publications the authors failed to provide sufficient detail for accurate replication of test procedures and the type of data analysis used (Keating & Matyas, 1996). Without a detailed description of the isokinetic test protocol it is impossible to reproduce the same test procedure and to compare different test results. Therefore, it is not fair to compare reference values of this study with results of other studies in competitive swimmers (Bak & Magnusson, 1997; McMaster et al., 1992; Rupp et al., 1995).

Between-group analysis resulted in non-significant differences and could be explained by different causes. First cause, the test groups were too small. There were not enough swimmers with recent shoulder complaints who wanted to be tested. The swimmers were afraid of new shoulder injuries and feared longer rehabilitation time. Second cause, the swimmers with shoulder complaints have a very high pain threshold and are used to swim with shoulder pain. Therefore, they are not much influenced by pain during the test and don’t quit easily. Third cause, the difference between the stroke pattern during swimming and the movements made by the subjects on the Biodex. Only the end internal rotation position in the test could be compared to the shoulder position during swimming between the early and late pull-through phase.

Results about the parameter FR could be compared with the studies of Beach et al. (1992) and Ellenbecker & Roetert (1999). Most parts in the test protocol of Beach et al. are in agreement with the test protocol in this study, but differences should be kept in mind for interpretation. Beach et al. used a fatigue protocol in competitive swimmers of 50 repetitions at 240°/sec measured with the Cybex II isokinetic dynamometer and calculated mean peak torque for the first and the last three repetitions. Swimmers were tested in prone position with 90° of shoulder abduction, 90° of elbow flexion, and the forearm in pronation. They reported mean fatigue ratios for respectively the left and right side of 80% and 78% for external rotation, and 106% and 107% for internal rotation, which is in agreement with the results in this study. Beach et al. reported a significant negative Pearson's correlation between isokinetic fatigue ratios of external rotation, abduction and shoulder pain. They concluded that the fatigue ratio becomes less when the swimmer experienced more shoulder pain.

In the study of Ellenbecker & Roetert (1999) seventy-two elite junior tennis players were tested at isokinetic muscular fatigue of the shoulder internal and external rotators. The tennis players completed 20 maximal-effort concentric contractions of external rotation and internal rotation at 300°/sec. The relative fatigue ratio was calculated by dividing the work in the last 10 repetitions by the work in the first 10 repetitions. They reported relative fatigue ratios ER and IR for the dominant extremity of 69,1% and 82,9%. In the non-dominant extremity, ER and IR fatigue ratios were 71,1% and 83,9%. The results from Ellenbecker & Roetert show significant differences between fatigue ratios for ER and IR.

The fatigue ratios of competitive swimmers in this study and the study of Beach et al. (1992) are higher than of tennis players in the study of Ellenbecker & Roetert (1999). This means that the shoulder rotators of competitive swimmers are better fatigue resistant than the of tennis players. Less fatigue of the external and internal rotators in swimmers would be expected due to sport-specific musculoskeletal adaptations from endurance training (Ellenbecker & Roetert, 1999).

Rotator cuff muscles play an important role in stabilising the shoulder joint during swimming motion and need to be resistant to muscle fatigue. In theory when the swimmers shoulder muscles get tired it becomes more difficult to stabilise the shoulder joint and to maintain proper stroke techniques during swimming. There could also exist a muscular imbalance as a result of less fatigue resistance of the external rotators than the internal rotators. This could be a factor in causing secondary impingement of the shoulder. It is important in rehabilitation of swimmers with shoulder complaints to train endurance capacities of rotator cuff muscles, especially external rotators, because it creates better muscle fatigue resistance and could prevent secondary impingement. In theory, training endurance capacities of the external rotators in swimmers could even help to prevent shoulder injuries.

Conclusion

The fatigue ratio external rotation for male swimmers with shoulder complaints measured by the Biodex multi-joint system is significantly lower at the involved side than at the uninvolved side. The ICC varied from poor repeatability to good repeatability for different parameters. In our opinion the less fatigue resistance of the external rotators at the involved side could be a causative factor in developing ‘swimmers shoulder’. This suggests that when evaluating competitive swimmers the clinician needs to be aware of the importance of assessing the fatigue ratio of shoulder external and internal rotators at 240°/sec. It could be helpful in developing a treatment protocol. More research should be done to study the effect of a shoulder treatment or prevention protocol in order to prevent ‘swimmers shoulder’.

Tables

Table 1. Description of the parameters.

Parameters	Description
ER-1	Mean of the first five peak torque repetitions of external rotation, 240°/sec and uninvolved side.
ER-2	Mean of the last five peak torque repetitions of external rotation, 240°/sec and uninvolved side.
ER-3	Mean of the first five peak torque repetitions of external rotation, 240°/sec and involved side.
ER-4	Mean of the last five peak torque repetitions of external rotation, 240°/sec and involved side.
IR-1	Mean of the first five peak torque repetitions of internal rotation, 240°/sec and uninvolved side.
IR-2	Mean of the last five peak torque repetitions of internal rotation, 240°/sec and uninvolved side.
IR-3	Mean of the first five peak torque repetitions of internal rotation, 240°/sec and involved side.
IR-4	Mean of the last five peak torque repetitions of internal rotation, 240°/sec and involved side.
ER/IR1-uninvolved	ER-1 : IR-1
ER/IR2-uninvolved	ER-2 : IR-2
ER/IR1-involved	ER-3 : IR-3
ER/IR2-involved	ER-4 : IR-4
FR-ER-uninvolved	ER-2 : ER-1 x 100
FR-ER-involved	ER-4 : ER-3 x 100
FR-IR-uninvolved	IR-2 : IR-1 x 100
FR-IR-involved	IR-4 : IR-3 x 100

Table 2. Descriptive statistics and frequencies of the swimmers (N=30)

Variables	**Male (N=21)**			**Female (N=9)**		
	Mean	**SD**	**Number**	**Mean**	**SD**	**Number**
Age (years)	19,8	2,6		18,9	2,7	
Length (cm)	187,2	6,5		170,7	8,2	
Weight (kg)	77,8	9,3		65,4	6,9	
Hand dominance						
Right			18			7
Left			3			2
Swimming club						
AZ&PC			10			6
DWK			7			2
De Haaien			3			0
Aquarijn			1			1
Stroke specialty						
Freestyle			10			4
Breaststroke			5			2
Backstroke			3			1
Butterfly			3			2
Shoulder complaints						
Yes			12			3
No			9			6

Table 3. Reference values of peak torque, mean peak torque, ER/IR and FR for swimmers with shoulder complaints (N=15) and swimmers without (N=15) shoulder complaints. All independent t-tests showed non-significant results ($p > .05$).

Parameters	**Swimmers without shoulder complaints Dominant side**		**Swimmers without shoulder complaints non-dominant side**		**Swimmers with Shoulder complaints uninvolved side**		**Swimmers with Shoulder complaints involved side**	
	Mean	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**
Peak torque ER 180 deg/sec (Nm)	30,5	25,9-34,9	31,4	26,3-36,5	35,3	30,9-39,7	34,7	31,7-37,9
Peak torque IR 180 deg/sec (Nm)	38,4	31,7-45,0	37,6	30,4-44,8	40,9	35,0-46,8	40,7	34,0-47,4
Peak torque ER 240 deg/sec (Nm)	29,1	24,7-33,5	30,1	24,6-35,6	32,7	28,5-37,0	33,2	29,4-37,0
Peak torque IR 240 deg/sec (Nm)	40,6	33,2-48,0	38,1	31,4-44,8	41,8	35,3-48,4	42,9	37,2-48,6
Mean peak torque ER first 5 rep.(Nm)	27,5	23,3-31,7	28,2	22,8-33,5	31,4	27,3-35,4	30,8	27,6-34,0
Mean peak torque ER last 5 rep. (Nm)	23,3	19,0-27,5	22,0	16,6-27,5	25,3	20,0-30,6	23,3	18,9-27,8
Mean peak torque IR first 5 rep. (Nm)	35,3	29,1-41,4	33,0	26,0-40,0	35,0	29,4-40,7	36,4	29,8-43,0
Mean peak torque IR last 5 rep. (Nm)	35,4	28,5-42,4	33,0	27,4-38,6	36,0	29,9-42,2	34,6	28,6-40,7
FR-ER (%)	83	78-89	76	64-89	78	65-91	73	62–86
FR-IR (%)	101	92–109	104	92–115	103	94–113	96	87–106
ER/IR1	0,81	0,71-0,91	0,88	0,78-0,98	0,95	0,78-1,13	0,91	75 – 106
ER/IR2	0,68	0,60-0,76	0,65	0,54-0,76	0,69	0,54-0,84	0,66	0,54-0,78

Table 4. Reference values of peak torque, mean peak torque, ER/IR and FR for male swimmers with shoulder complaints (N=12)

Parameters	**Uninvolved side**		**Involved side**	
	Mean	**95% CI**	**Mean**	**95% CI**
Peak torque ER 180 deg/sec (Nm)	38,6	35,7-41,5	36,9	34,4-39,3
Peak torque IR 180 deg/sec (Nm)	43,6	37,8-49,3	43,0	35,4-50,6
Peak torque ER 240 deg/sec (Nm)	35,5	31,8-39,2	35,6	32,2-39,0
Peak torque IR 240 deg/sec (Nm)	44,9	38,2-51,5	46,2	41,0-51,3
Mean peak torque ER first 5 rep. (Nm)	34,2	31,2-37,3	32,9	30,2-35,5
Mean peak torque ER last 5 rep. (Nm)	29,3	26,8-31,9	26,1	23,4-28,9
Mean peak torque IR first 5 rep. (Nm)	37,4	31,8-43,0	38,5	31,0-46,1
Mean peak torque IR last 5 rep. (Nm)	39,6	34,3-44,9	37,6	31,5-43,7
FR-ER (%)	86	82-90	79	75-83
FR-IR (%)	107	97-118	100	89-112
ER/IR1	0,95	0,80-1,11	0,92	0,73-1,11
ER/IR2	0,76	0,66-0,88	0,72	0,65-0,79

Table 5. Significancy values paired t-tests for male swimmers with shoulder complaints (N=12).

Pairs	Significancy (2-tailed)
ER1 – ER2	,000*
IR1 – IR2	,192
ER3 – ER4	,000*
IR3 - IR4	,494
FR-ER uninvolved – FR-ER involved	,001*
FR-IR uninvolved – FR-IR involved	,394
ER1 – ER3	,342
IR1 - IR3	,666
ER2 – ER4	,009*
IR2 - IR4	,326

*p < .05

References

Allegrucci, M., Whitney, S.L., & Irrgang, J.J. (1994). Clinical implication of secondary Impingement of the shoulder in freestyle swimmers. *Journal of Orthopaedic & Sports Physical Therapy*, **20**, 307-318.

Bak, K., & Magnusson, S.P. (1997). Shoulder strength and range of motion in symptomatic and pain-free elite swimmers. *The American Journal of Sports Medicine*, **25**, 454-459.

Beach, M.L., Whitney, S.L., & Dickoff-Hoffman, S.A. (1992). Relationship of shoulder flexibility, strength, and endurance to shoulder pain in competitive swimmers. *Journal of Orthopaedic & Sports Physical Therapy*, **16**, 262-268.

Biodex corporation (1990). *Multi-joint System Manual* (third edition). Biodex medical systems Inc., Brookhaven R & D Plaza, Shirley, New York.

Cingel, E.H.R., Aufdemkampe, G., & Bois, R. du (1997). Isokinetische testresultaten van knie- en schoudermusculatuur bij mannelijke topvolleyballers. *Geneeskunde en Sport*, **30**, 98-106.

Dvir, Z. (1995). *Isokinetics: muscle testing, interpretation and clinical applications.* Churchill Livingstone.

Ellenbecker, T.S., & Roetert, E.P. (1999). Testing isokinetic muscular fatigue of shoulder internal and external rotation in elite junior tennis players. *Journal of Orthopaedic & Sports Physical Therapy*, **29**, 275-281.

Fowler, P.J., & Forwell, L. (1999). Swimming. In R.C Bull (ed.), *Handbook of Sports Injuries* (pp. 485-512). McGraw-Hill companies, Inc.

Friseillo, S., Gazaille, A., O'Halloran, J., Palmer, M.L., & Waugh, D. (1994). Test-retest reliability of eccentric peak torque values for shoulder medial and lateral rotation using the Biodex isokinetic dynamometer. *Journal of Orthopaedic & Sports Physical Therapy*, **19**, 341-344.

Johnson, J.E., Sim, F.H., & Scott, S.G. (1987). Musculoskeletal injuries in competitive swimmers. *Mayo Clinic Proceedings*, **62**, 289-304.

Kamkar, A., Irrgang, J.J., & Whitney, J.L. (1993). Nonoperative management of secondary shoulder impingement syndrome. *Journal of Orthopaedic & Sports Physical Therapy*, **17**, 212-224.

Keating, J.L., & Matyas, T.A. (1996). The influence of subject and test design on dynamometric measurements of extremity muscles. *Physical Therapy*, **76**, 866-889.

Kenal, K.A.F., & Knapp, L.D. (1996). Rehabilitation of injuries in competitive swimmers. *Sports medicine*, **22**, 337-247.

McMaster, W.C., Long, S.L., & Caiozzo, V.J. (1992). Shoulder torque changes in the swimming athlete. *The American Journal of Sports Medicine,* **20**, 323-327.

McMaster, W.C., & Troup, J. (1993). A survey of interfering shoulder pain in United States swimmers. *The American Journal of Sports Medicine*, **21**, 67-70.

Murphy, T.C. (1994). Shoulder injuries in swimming. In J.R. Andrews & K.E. Wilk (eds.). *The athlete's shoulder* (pp. 411-424). Churchill Livingstone.

Pink, M., Perry, J., Browne, A., Scovazzo, M.L., & Kerrigan, J. (1991). The normal shoulder during freestyle swimming. An electromyographic cinematographic analysis of twelve muscles. *The American Journal of Sports Medicine*, **19**, 569-576.

Portney, L.G., & Watkins, M.P. (1993). *Foundations of Clinical Research applications to practice*. Appleton & Lange, Stamford, Connecticut.

Rupp, S., Berninger, K., & Hopf, T. (1995). Shoulder problems in high level swimmers - impingement, anterior instability, muscular imbalance? *International Journal of Sports medicine*, **16**, 557-562.

Scovazzo, M.L., Browne, A., Pink, M., Jobe, F.W., & Kerrigan, J. (1991). The painful shoulder during freestyle swimming. An electromyographic cinematographic analysis of twelve muscles. *The American Journal of Sports Medicine*, **19**, 577-582.

SPSS statistical analysis package, version 8.0. United Kingdom.

Wingerden, B.A.M. van (revised version 1997). *Bindweefsel in de revalidatie* (translated in Dutch by Hoepen, E. van). SCIPRO Verlag Schaan Liechtenstein.

Yanai, T., & Hay, J.G. (2000). Shoulder impingement in front-crawl swimming: II. analysis of stroking technique. *Medicine & Science in Sports & Exercise*, **32**, 30-40.

Appendices

Appendix A

Journal of Applied Biomechanics

Submissions Guidelines

The primary criteria on which manuscripts submitted to the Journal of Applied Biomechanics are judged include adherence to accepted scientific principles and methods, contribution of the work to applied biomechanics, clarity and conciseness of the writing, and interest to the readership. Following are the types of submissions that are considered.

Original Articles: Original articles present the results of a hypothesis-driven study or, in some cases, a descriptive study, the results of which are considered novel and important. Original articles should not generally exceed 3,500 words and should not include more than eight graphics.

Technical Notes: Technical notes are short communications that present results related to a new or modified method or instrument or an important experimental observation that are of interest to the readership. Technical notes should generally not exceed 1,500 words and should not include more than four graphics.

Rapid Communications: Rapid Communications are intended for substantive new results that merit editorial consideration to minimize the elapsed time between receipt and publication. Authors should provide in their cover letter the rationale for this special consideration. Rapid Communications should not exceed 1,500 words and should not include more than four graphics.

Reviews/Symposium or Workshop Proceedings: Reviews are critical and inclusive presentations of important aspects of biomechanics. Symposium or workshop proceedings comprise a number of brief papers, each based on an individual presentation that was part of a larger, focused program. Reviews and proceedings are solicited by Editorial Board members, although authors may contact the Editor regarding the suitability of their review and symposium/workshop manuscripts.

Target Articles: Target articles present a summary of current scientific thought and the unique perspective of an experienced scientist on a matter that is significant to the field of biomechanics. Invited responses to the target article and the author's rebuttal are normally published with the target article.

Four clean copies of the manuscript should be submitted to the Editor, Mark D. Grabiner, PhD, Department of Biomedical Engineering, Wb3, The Cleveland Clinic Foundation, 9500 Euclid Ave., Cleveland, OH 44106. Authors must state in the cover letter that the manuscript has not been published in another journal (except in abstract form), is not presently under consideration by another journal, and will not be submitted to another journal before a final editorial decision from JAB is rendered. Authors of manuscripts accepted for publication in JAB must transfer copyright to Human Kinetics. The review process will not be a blind process unless specifically requested by the authors in the cover letter.

Authors are strongly encouraged to carefully proofread their manuscripts and pay particular attention to the clarity of writing. All manuscripts should have an abstract of 200 words. A cover sheet on each copy of the manuscript should include the manuscript's title, the full names of each author, each author's institution, a brief running head, three to five key words that do not appear in the title of the manuscript, and the date of manuscript submission. For the listed corresponding author, provide a full mailing address, phone number, fax number, and e-mail address. The author must provide a statement regarding any financial interest in the research.

Authors should follow the guidelines found in the Publication Manual of the American Psychological Association, 4th edition, 1994 (APA, Order Department, P.O. Box 2710, Hyattsville, MD 20784-0710). The entire manuscript must be double spaced. All figures must be professional quality and camera-ready. Figures may be submitted on disk if they are created in Macintosh Illustrator or Freehand or are saved in eps, tiff, or pict format.

Human kinetics: submissions Guidelines – JAB
http://www.hkusa.com/products/journals/submissions.cfm?jid=JAB

Appendix B

Translated Dutch Questionnaire

1. At what age did you first swim competitively?
2. Do you practice any other sport than swimming?
3. What is your hand dominance?
4. What is your favourite swimming stroke?
5. How many swimming practices do you swim per week?
6. What is the duration of a swimming practice?
7. How many metres per day do you swim in workouts?
8. Do you perform a warm-up before starting swimming?
9. Do you stretch your muscles before practice?
10. If yes, which muscles, when and how many seconds do you stretch?
11. Do you get instructions for stretching?
12. If yes, by who?
13. What is the duration of the warm-up during swimming practice?
14. What is the duration of the warm-up during a competition match?
15. How many percent of the swimming practice is freestyle?
16. At what side do you breathe during freestyle?
17. Do you use swimming paddles during practice?
18. If yes, what is the purpose of training with swimming paddles?
19. Do you perform weight training?
20. If yes, how many times a week, what is the duration of a workout and what do you train?
21. Do you perform any other kind of training?
22. If yes, what do you do?
23. Did you ever have shoulder complaints?
24. If yes, when?
25. Do you have shoulder complaints right now?
26. If yes, when did it start?
27. Give a description of your shoulder complaints?
28. At what arm do you have shoulder complaints and what is the location of the pain?
29. When do you have shoulder complaints (at the beginning, during or after a swimming practice or swim match)?
30. Do you have pain when your shoulder is not moving?
31. Witch swimming stroke provokes the shoulder complaints the most?
32. During what phase of the swimming stroke pattern do you have pain (the catch, early pull-through, late pull-through and/or recovery)?
33. Did you take medication for your shoulder complaints?
34. Did you ever have a shoulder injection?
35. Did you ever have a shoulder surgery?
36. Did you ever have a shoulder luxation?
37. Did you ever have any other injuries with swimming?
38. If yes, which injuries?

Appendix C

Results Questionnaire

Table a. Descriptives of the answers of the questionnaire (N=46 swimmers).

Variables	***Mean***	***Standard Deviation***
Age onset of swimming	8.0 years old	3.33
Age	19.3 years old	3.14
Number of swimming practices a week	7.9 practices	1.86
Swimming practice duration	1.6 hours	0,29
Mean distance by swimming practice	4.4 kilometres	0.79
Number of months training per annum	10.5 months	0.67
Mean distance of warm-up during swimming practice	1110 metres	256
Mean distance of warm-up during competition match	864 metres	313
Percentage of freestyle during a swimming practice	69,5 %	13
Number of weight training a week	2.1 practices	0.53
Weight training duration	1.4 hours	0.37

Table b. Numbers and percentages of the answers of the questionnaire (N=46 swimmers)

Variables	***Options***	***Number***	***Percentage (%)***
Arm dominance	Right	40	87,0
	Left	6	13,0
Sex	Male	31	67,4
	Female	15	32,6
Swimming club	AZ&PC	19	41,3
	DWK	14	30,4
	De Haaien	6	13,0
	Aquarijn	7	15,2
Stretching	Yes	32	69,6
	No	7	15,2
	Sometimes	7	15,2
Instructions stretching	Yes	25	54,3
	No	14	30,4
	Sometimes	7	15,2
Instructions for stretching given by	Coach	23	50,0
	Weight trainer	4	8,7
	Physical therapist	6	13,0
Warm-up prior to swim practice	Yes	13	28,3
	No	16	34,8
	Sometimes	17	37,0
Other sports	Yes	23	43,5
	No	23	56,5
Which sports	Running	9	19,6
	Biking	10	21,7
	Other	4	8,7
Weight training	Yes	43	93,5
	No	3	6,5
Training with swimming paddles	Yes	34	73,9
	No	12	26,1
Purpose training with swimming paddles	Strength/power	20	43,5
	Stroke techniques	14	30,4
Breathing side freestyle	Both sides	26	56,5
	Left	7	15,2
	Right	13	28,3
Previous shoulder complaints	Yes	26	56,5
	No	20	43,5
Present shoulder complaints	Yes	9	19,6
	No	34	73,9
	Sometimes	3	6,5
Other injuries	Yes	27	58,7
	No	19	41,3
Location other injuries	Knee	12	26,1
	Elbow	7	15,2
	Back	6	13,0
	Other	8	17,4

Appendix D

Referenties situering

Cingel, E.H.R., Aufdemkampe, G., & Bois, R. du (1997). Isokinetische testresultaten van knie- en schoudermusculatuur bij mannelijke topvolleyballers. *Geneeskunde en Sport*, **30**, 98-106.

Dvir, Z. (1995). *Isokinetics: muscle testing, interpretation and clinical applications.* Churchill Livingstone.

Scovazzo, M.L., Browne, A., Pink, M., Jobe, F.W., & Kerrigan, J. (1991). The painful shoulder during freestyle swimming. An electromyographic cinematographic analysis of twelve muscles. *The American Journal of Sports Medicine*, **19**, 577-582.