UNIVERSITEIT GENT

FACULTEIT GENEESKUNDE EN GEZONDHEIDSWETENSCHAPPEN

Rehabilitation Sciences and Physiotherapy
Academic year 2015-2016

THE EFFECT OF A SIX WEEKS ECCENTRIC TRAINING PROGRAM ON THE SHOULDER EXTERNAL ROTATOR STRENGTH AND THE ROTATOR CUFF STRENGTH RATIO IN HEALTHY OVERHEAD ATHLETES

A SINGLE-BLINDED RANDOMIZED CONTROLLED TRIAL

Master's dissertation submitted to obtain the degree of
Master of Science in Rehabilitation Sciences and Physiotherapy

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DANKWOORD

Deze masterproef was een zeer omvangrijke maar uitdagende opdracht om onze studie in schoonheid te kunnen afsluiten. Aangezien dit niet alleen ons werk is geweest, willen we via deze weg onze oprechte dank uitdrukken aan iedereen die heeft bijgedragen tot het realiseren van deze masterproef.

Allereerst willen wij onze promotor Prof. Dr. Ann Cools bedanken voor de uitstekende samenwerking, toegankelijkheid en het snel beantwoorden van onze vragen tijdens het tweede masterjaar. Onze keuze voor dit onderwerp kwam mede tot stand door haar inbreng, de gedreven manier waarop zij les gaf en het aanbrengen van uiterst interessant lesmateriaal gedurende onze vijfjarige opleiding. Ook zouden wij Dr. Annelies Maenhout, onze vorige promotor, willen bedanken voor haar uitstekende begeleiding bij de systematische review en de testing tijdens de maanden augustus en september. De kritische blik en steun van onze beide promotors hebben deze masterproef mee tot stand gebracht.

Een masterproef met dergelijk uitgebreide testing zou niet tot stand kunnen komen zonder de bereidwilligheid en spontane medewerking van proefpersonen. We zouden via deze weg alle bovenhandse sporters willen bedanken om zich zonder compensatie tweemaal te verplaatsen naar het UZ Gent en zich maximaal in te zetten.

Tot slot willen we ook onze ouders bedanken. Van hen kregen we de kans om te studeren en zo een basis te leggen voor onze toekomst. Ook onze partners en broer/zus willen we danken voor hun steun en geduld tijdens de moeilijke momenten.

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BERLAAR, 12 mei 2016

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SINT-NIKLAAS, 12 mei 2016

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LIST OF ABBREVIATIONS

ER	External rotation
ROM	Range of motion
IR	Internal rotation
PT	Peak torque
PT/BW	Peak torque to body weight
COVAR	Coefficient of variance
TTPT	Time to peak torque
TW	Total work
Con	Concentric
Ecc	Eccentric

ABSTRACT

BACKGROUND: Lower ER strength and lower ER/IR ratio tend to lead to a higher risk on developing shoulder injuries in overhead athletes. Today it is still not clear how to influence ER strength and ER/IR ratios.

OBJECTIVE: The aim of this study was to investigate whether a six weeks eccentric training program on the external rotator strength could improve the ER strength and the ratio con ER/con IR in healthy overhead athletes.

STUDY DESIGN: Single-blinded randomized controlled trial (RCT)

METHODS: Participants were randomly assigned to a control or intervention group. Having both fulfilled an isokinetic testing, the intervention group only received a six weeks eccentric training program which consisted of three eccentric ER exercises for the dominant shoulder. Exercises were performed using different colors of Thera Band with increasing resistance and number of repetitions. Six weeks of continuing their normal overhead sport activities, all participants fulfilled a second isokinetic testing.

RESULTS: Both con ER, con IR and ecc ER results did not improve after an ecc ER training program. Con ER increased through time in both groups, which resulted in a greater ratio. In both con ER and IR at 240°/s, the intervention group had higher results post-testing for work fatigue.

CONCLUSION: The present study implies that a six weeks eccentric ER strength training program has no effect on ER strength and con ER/con IR ratio.

KEYWORDS: Overhead athletes, Eccentric training program, External rotation, Ratio, Rotator cuff

ABSTRACT NEDERLANDS

ACHTERGROND: Een lagere exorotatiekracht en een lagere exo-/endorotatie ratio blijken te leiden tot een hoger risicio op het ontwikkelen van schouderletsels bij bovenhandse atleten. Het is vandaag echter nog niet duideijk hoe deze exorotatiekracht en ratio te beïnvloeden zijn.

DOELSTELLING: Het doel van deze studie was om te onderzoeken of een 6 weken durend excentrisch traininingsprogramma voor de exorotatoren de exorotatiekracht en de exo-/endorotatiekracht ratio kan verbeteren bij gezonde bovenhandse atleten.

ONDERZOEKSDESIGN: Enkelgeblindeerd gerandomiseerd gecontroleerd onderzoek

METHODE: Deelnemers werden gerandomiseerd toegewezen aan een controle- of interventiegroep. Nadat beide groepen een isokinetische testing ondergingen, deed enkel de interventiegroep een 6 weken durend excentrisch trainingsprogramma dat bestond uit 3 excentrische exorotatie-oefeningen voor de dominante schouder. De oefeningen werden uitgevoerd met behulp van verschillende kleuren Thera Band met progressieve weerstand en aantal herhalingen. Na 6 weken van normale sportactivitiveiten ondergingen alle deelnemers een tweede isokinetische testing.

RESULTATEN: Zowel de concentrische exo- en endorotatiekracht als excentrische exorotatiekracht verbeterden niet als gevolg van een excentrisch trainingsprogramma van de exorotatoren. De concentrische exorotatiekracht verbeterde in beide groepen doorheen de tijd, wat resulteerde in een hogere ratio. In zowel de concentrische exorotatie- als endorotatiekracht bij 240°/s had de interventiegroep hogere resultaten voor work fatigue bij de tweede testing.

CONCLUSIE: Deze studie toont aan dat een 6 weken durend excentrisch trainingsprogramma van de exorotatoren geen effect heeft op de exorotatiekracht en de concentrische ER/IR ratio bij gezonde bovenhandse sporters.

SLEUTELWOORDEN: Bovenhandse sporters, Excentrische training, Externe rotatie, Ratio, Rotator cuff

INTRODUCTION

The demand of an overhead athlete's shoulder is extremely high. Therefore, due to the high extent of forces during the unique and sports-specific movement, the overhead athlete is at great risk for injuries of the shoulder joint.

The dominant shoulder often needs a delicate balance between mobility and stability. The shoulder requires high flexibility to allow excessive external rotation (ER) and abduction while it needs its stability to avoid humeral head subluxations during rapid overhead movements(23).

Each overhead sport such as volleyball, handball, baseball, tennis, throwing, softball and many others, has its own specific movement pattern. During these movement patterns, rotator cuff and capsulolabral structures act to stabilize the humeral head on the glenoid fossa(12). Because of this dynamic stabilization, rotator cuff, labrum and capsule are frequently injured locations.

Knowledge about overhead, and more specific throwing-biomechanics, is essential and very important in the treatment of these athletes. In a throwing movement, energy is transferred from the lower extremities to the trunk and ultimately to the upper extremity via a kinetic chain(1). When a kinetic chain "breakage" is present, it will have impact on the whole motion biomechanics and will possibly induce injuries.

Overhead athletes often suffer from injury and chronic pain(14). In most of these cases, a conservative treatment is highly recommended. On top of this conservative treatment, physiotherapists should prepare and advise an injury prevention program for any overhead athlete. It would be very helpful to avoid injuries and maintain a good muscular balance, scapular control (SC), mobility and more.

Previous research demonstrated that injuries or chronic pain can lead to adaptations of the shoulder in overhead activities(4).

In a previous systematic review(5), risk factors for shoulder injuries in overhead athletes were examined. It has been found that there is an association of lower ER strength and lower SS strength with shoulder injuries. A lower ER/IR ratio could also be linked to the prevalence of shoulder injuries. Forthomme et al.

(2013) found that the eccentric maximal strength developed by the IR and ER has been proven a protective factor. A more recent search task (15th of November, 2015) led us to two new articles that show new and confirmed previous risk factors for shoulder injuries. Shitara et al. (2015) demonstrates that a low prone external rotation ratio in the dominant to non-dominant side is a significant risk factor for shoulder injuries in high school baseball pitchers(22). Pontillo et al. (2015) tested pre-season strength in collegiate football players(19). The variables that were significantly correlated with injury were forward elevation strength in a full can position and prone-Y to fatigue that tested the endurance of the middle and lower trapezius muscles.

During throwing and smashing movements, the internal rotator muscles of the athlete's shoulder accelerate the shoulder concentrically from maximal external rotation to ball impact before the external rotators start to work eccentrically to decelerate this movement(11). Recent literature describes the attempt of identifying a functional relationship in internal and external rotator muscles(15,16,17,21,24) besides the more traditional ER/IR ratio both measured in a concentric mode. All this to establish a functional ratio of the eccentric external rotator strength to the concentric internal rotation strength. Ratios reported ranges from 1.08 to 1.17, which means that the eccentric ER strength needs to be equal to or higher than the concentric IR strength. Deceleration of the concentrically internal rotation and other forces associated with the dynamic nature of the overhead throwing or smashing motion need to be conquered by the eccentric external rotation.

In recent scientific literature, no isolated eccentric strength training programs for the external rotators were found. A few studies are describing the effect of eccentric strength training, but the reported exercises consist of a concentric phase to finally get to the starting position of the eccentric phase. On one hand, the (total work) ratio ecc ER/ con IR has increased in an isokinetic strength training program(16), but on the other hand the ecc ER/ con IR ratio in a plyometric training group was not statistically significantly differing from the one in a control group(3). Ellenbecker et al. (1988)(7) describes concentric strength gains in both concentric and eccentric training and only eccentric strength gains in concentric training, not in eccentric training. Otherwise, Mont et al. (1994)(13) investigated statistically significant concentric and eccentric strength gains in both concentric and eccentric training groups when compared with control groups. A fifth study reports a significantly greater increase in the eccentric group for absolute difference in peak force and peak torque compared to a combined concentric and eccentric group[2]. No clear results from strength training programs are reported in the latest literature.

Based upon previous literature, we can carefully conclude that a higher strength of the eccentric external rotators could possibly prevent injuries of an overhead athlete's shoulder. However, evidence about the effects of an eccentric training program on eccentric strength and functional ER/IR ratios is scarce. Therefore, the purpose of this study is to examine the effect of a six weeks eccentric training program of the external rotators of the shoulder (I) in healthy overhead athletes (P), and compare their results to a control group (C), only performing their normal training and competition schedule in the same period. The isokinetic strength (O) is measured by use of a Biodex. In this study, there is been hypothesized that isolated eccentric strength training for the external rotators will exclusively improve the eccentric strength of the external rotators, improve con ER/ con IR ratio and thus prevent injuries in overhead athletes.

METHODS

A single-blinded randomized clinical trial was conducted by two physiotherapy students of the University of Ghent.

Participants

Between June and August 2015, participants were recruited through personal approach, by mail or social media. Participants were included if they fulfilled the following inclusion criteria: (1) healthy male/female overhead athlete, (2) age 18-35, (3) sports: volleyball, basketball, korfball, javelin, handball, badminton and/or tennis, (4) at least 4h of weekly training and/or matches, (5) minimum of 2 years of experience in the respective sport, (6) no history of shoulder complaints during the last 6 months, (7) no previous fractures in the shoulder region, (8) no history of surgery in the shoulder region. Athletes who did not meet all 8 inclusion criteria were excluded from this study.

At the start of the first testing period, a total number of 39 athletes were included. In the end, 36 athletes (23 women and 13 men) finished the whole examination procedure. Two dropouts were recorded due to practical reasons. One dropout was recorded due to a biceps injury of the non-dominant shoulder.

In the study population of 36 athletes, mean (± standard deviation) age, height, weigth, total hours of sport/week and years of experience were 22,1 ± 2,1 years, 177,4 ± 9,6 cm, 70,9 ± 11,1 kg, 8,5 ± 2,7 hours and 14,6 ± 3,2 years, respectively (Table 1). Fourteen athletes played volleyball, 5 basketball, 6 korfball, 4 javelin, 2 handball, 3 badminton and 2 tennis. Thirty-five athletes were right-handed, only 1 athlete was left-handed.

	Control group	**Intervention group**	**TOTAL**
Total/group	18	18	36
Age (year)	21,6 ± 2	22,7 ± 2,2	22,1 ± 2,1
Heigth (cm)	176,4 ± 9,3	178,3 ± 10,1	177,4 ± 9,6
Weight (kg)	67,9 ± 9,8	73,7 ± 11,8	70,9 ± 11,1
Total hours of sport/week	8,1 ± 2,4	9 ± 3	8,5 ± 2,7
Years of experience	14,1 ± 2,7	15,2 ± 3,6	14,6 ± 3,2
Right handed (left handed)	18 (0)	17 (1)	35 (1)

Table 1: Anthropometric measurements

Research protocol

The testing was performed in a laboratory at the Physiotherapy Department at the University of Ghent. The first testing period took place between August 14th and September 4th. Re-testing was held between September 23th and October 16th, considering a time interval of 5 to 7 weeks between the two periods.

Prior to submitting them to the actual isokinetic measurements, participants were informed about the purpose of this study and were requested to sign an Informed Consent. One researcher then explained the testing procedure.

At the start, a standard warming-up with a low resistance Thera Band was performed, consisting of 3 times 15 repetitions of internal and external rotation in neutral position of the shoulder (0° of abduction and elevation) and with the elbow flexed at 90°.

The isokinetic strength was measured by use of a Biodex System 4 isokinetic dynamometer (Biodex Medical Systems, Shirley, NY) with a protocol described in

Dvir Z (2003)[6]. Athletes were tested in a seated position with the trunk fixated with help of a belt. Legs were not supported. High test-retest reliability for the internal and external rotator muscles was previously demonstrated, which allows a reliable post-testing when compared to the pre-testing[18].

The shoulder was positioned in 30° of elevation in the scapular plane, with a flexed elbow at 90° and forearm supported. Forearm and wrist were held in a neutral position. A stick was held with the hand.

Isokinetic strength of the internal and external rotators was tested both concentric and eccentric. Concentric strength was measured at 3 different testing speeds: 60°/s, 180°/s and 240°/s, eccentric testing only at 30°/s. Both dominant shoulder and non-dominant shoulder were tested, always starting with the dominant side. Concentric testing always started at 60°/s followed by 180°/s and 240°/s. In between, participants had a break of 30 seconds.

Each test was preceded by submaximal trial repetitions: 5 for each concentric test and 3 for both eccentric tests. Approximately 2 seconds after the trial reps, the actual test was started, consisting of 5 repetitions for concentric testing at 60°/s and 10 repetitions for both 180°/s and 240°/s. Eccentric internal and external rotation was performed in 3 repetitions.

The sequence of testing was randomized by use of the website www.randomizer.org. The concentric testing got number 1, eccentric external rotation number 2 and eccentric internal rotation number 3. For example, an athlete had sequence 2-3-1. This means the athlete performed task 2 on his dominant side prior to the non-dominant side and then the same for task 3 and 1. The same sequence was followed when the athletes performed the second testing.

The two researchers had different tasks. Researcher 1 adjusted the Biodex while researcher 2 took care of the computer work. The latter asked the athletes about height, weight and date of birth. Researcher 2 was blinded for the intervention and encouraged every athlete in an equally standardized way.

After every different test (number 1, 2 of 3), both researchers checked COVAR (coefficient of variation). The COVAR determines the reproducibility of the test, based on the amount of variation between repetitions. In general, it is suggested that the COVAR for testing of "large" muscle groups such as the rotator cuff should be below 15%[6]. If COVAR of the first attempt was higher than 13%, a new test needed to be executed after approximately one minute. If the COVAR of the second attempt was again more than 13%, no extra effort was performed because of the fatigue factor.

Subsequent outcome parameters were registered for the concentric testing: peak torque (PT), peak torque per body weight (PT/BW) and agonist/antagonist ratio (ER/IR ratio). For eccentric testing following outcome parameters were considered: peak torque (PT), peak torque per body weight (PT/BW), total work (TW), work fatigue (WF) and agonist/antagonist ratio (ER/IR ratio).

Intervention

Athletes were assigned to a control group or to an experimental training group with use of blocked randomization. Athletes of the control group did not receive a training program and were asked to continue their actual daily trainings and matches. Athletes allocated to the experimental training group received a strength training program to be performed 3 times a week, in addition to their normal training and matches. This strength training program for the dominant shoulder consisted of 3 exercises for the eccentric external rotational strength: (1) seated eccentric external rotation, (2) supine eccentric external rotation and (3) standing eccentric external rotation (see Figure 1). The exercises were executed with help of a Thera Band.

Figure 1: (1) seated (can also be in standing position) – (2) supine – (3) standing eccentric external rotation

Exercise 1 – Seated (can also be in a standing position)	Starting position: • Elbows 90° flexed, Thera Band in both hands • External rotation D shoulder in combination with internal rotation of non-D shoulder Execution: • First external rotation of non-D shoulder • Slow internal rotation of D shoulder
Exercise 2 – Supine	Starting position: • Thera Band around homolateral foot, knee flexed • Shoulder in 90° abduction and 90° of external rotation Execution: • Knee extension • Slow internal rotation of the shoulder
Exercise 3 – Standing	Starting position: • Thera Band around non-D foot, held with both hands, elbows 90° flexed • Thera Band brought to 90° abduction and 90° of external rotation by both hands • Non-D hand let Thera Band go Execution: • Slow internal rotation of D shoulder to non-D hip (diagonal)

Table 2: Explanation of eccentric exercise program

Researcher 1 explained and demonstrated above-mentioned 3 exercises and e-mailed the exercises fully explained with text, pictures and video. Researcher 2 was blinded for the group allocation.

The athletes performed a 10RM test to decide which color of Thera Band they needed to start with. The athletes were given the determined color of Thera Band and another color with increasing resistance. Athletes were asked to start the exercise program two days after the Biodex-testing. At the start of the 6 weeks strength training program, every exercise needed to be executed 3 times 10 repetitions. Athletes were informed that they needed to have a subjective feeling of muscle fatigue at the end of the exercise. Progressively, they performed the exercises 3 times 15 reps and finally 3 times 20. The next step of progression was another color of Thera Band with increased resistance, repeating the progressive execution of exercises. Athletes were asked to complete a diary in which they wrote down in detail the color of Thera Band, amount of repetitions, pain during exercise and pain during the day. Researcher 1 (non-blinded) contacted everyone after approximately 3 weeks to track progression and to inform for possible remarks or questions the athletes might have. Approximately 6 weeks after the first testing, athletes of both control group and experimental training group performed the same strength testing with the same protocol and order of testing.

Statistical analysis

Statistical analysis was performed by using SPSS IBM Statistics (version 23.0, released 2015. Property of IBM Corp. ©). One-sample Kolmogorov-Smirnov test was used to determine normal distribution. Data with a non-normally distribution were checked by use of a boxplot. As all outcome variables were normally distributed, parametric tests were performed for further analysis. Anthropometric measurements of both groups were analyzed by using independent t-tests. Mean values and significance were studied, no significant differences ($p<0,05$) in age (y), length (cm), weight (kg), total hours of sport/week and years of experience were noted.

Further statistical analysis was studied using ANOVA with repeated measures. The within-subjects factors were time (pre-testing and post-testing) and side (dominant and non-dominant). The between-subjects factor was group (control or training group). Post-hoc tests (Bonferroni) were performed to clarify the two side interaction effects, as there were no three-way interaction effects. In case of main effects for side, group or time, no post hoc test was performed.

RESULTS

For con ER, there was no significant interaction effect of time * side * group. For ER at 60°/s, a significant time effect was measured for PT/BW and for the ratio ER/IR. Both variables increased through time. Also a side effect was measured for the ratio ER/IR where non-dominant sides had higher ratios.
At 180°/s, a time * side effect was measured for PT/BW. For both pre and post-testing, no significant differences were observed in PT/BW between dominant and non-dominant sides. Although there was a significant difference in PT/BW at the dominant side pre- and post-testing, which means the dominant side became stronger through time. A significant time effect was also observed for PT and PT/BW, where both results increased through time. A side effect was noticed for the ratio ER/IR, where non-dominant sides had higher ratios.
At 240°/s, a significant time * group effect was measured for work fatigue. Pre-testing, a significant difference was noticed between control and intervention group. Work fatigue in control group was significantly higher. In the intervention group, a significant increase in work fatigue through time was observed. Significant time effects for both PT, PT/BW and ratio ER/IR were observed, where all variables increased. Also a significant side effect for ratio ER/IR was noticed, with higher ratios at the non-dominant side (Table 9).

Also for con IR as well, no significant interaction effect of time * side * group were observed. At 60°/s, only significant side effects for PT and PT/BW were noticed, with higher results at the dominant side. For con IR at 180°/s, also only side effects for PT, PT/BW and work fatigue were observed as well, with higher results at the dominant side. For con IR at 240°/s, a significant time * group effect was observed for work fatigue. Pre-testing, a significant difference was noticed between control and intervention group. Work fatigue in control group was significantly higher. In the intervention group, a significant increase in work fatigue through time was observed. For con IR at 240°/S, a significant side effect for PT and PT/BW was measured, with higher results at the dominant side (Table 10).

Concerning the eccentric isokinetic measurements, only significant side effects were noticed at ecc IR at 30°/s for PT and PT/BW with higher results at the dominant side (Table 11).

		Control group		Intervention group	
		Non-dominant	Dominant	Non-dominant	Dominant
Pre-testing	**Con exo 60° PT**	24,1 ± 8,7	24 ± 7,7	25,4 ± 9,1	25,8 ± 8,6
	Con endo 60° PT	31 ± 12,3	33,4 ± 11,5	35,8 ± 16,4	38,2 ± 17,2
	Ratio con ER/con IR 60°	79,8 ± 11,5	73,2 ± 10,7	75,6 ± 15,6	71,4 ± 13
	Con exo 60° PT/BW	34,9 ± 8,9	35 ± 8,4	33,9 ± 9	34,6 ± 8,5
	Con endo 60° PT/BW	44,9 ± 13,6	48,7 ± 12,9	47,3 ± 17,4	50,9 ± 18,5
Post-testing	**Con exo 60° PT**	24,4 ± 8,4	24,5 ± 7,1	26,5 ± 8,8	26,9 ± 8,1
	Con endo 60° PT	29,4 ± 11,4	32,4 ± 12,1	34,1 ± 14,5	37,5 ± 14,2
	Ratio con ER/con IR 60°	84,7 ± 13	78,2 ± 9,7	80,8 ± 12	74,6 ± 13,1
	Con exo 60° PT/BW	35,3 ± 8,4	35,8 ±7	35,5 ± 8,6	36,2 ± 8,1
	Con endo 60° PT/BW	42,4 ± 11	46,8 ± 11,9	45,5 ± 16	50 ± 14,4

Table 3: Descriptive statistics - concentric 60°/sec (PT, PT/BW, ratio)

		Control group		Intervention group	
		Non-dominant	Dominant	Non-dominant	Dominant
Pre-testing	**Con exo 180° PT**	19,9 ± 7,9	19 ± 7	20,8 ± 7,7	20,6 ± 7,4
	Con endo 180° PT	27,5 ± 10	29,8 ± 10,3	30,9 ± 13,4	33,9 ± 15
	Ratio con ER/con IR 180°	72,2 ± 9,1	64 ± 9,7	70,3 ± 13,8	63,4 ± 10,4
	Con exo 180° PT/BW	28,8 ± 8,5	27,6 ± 8	27,7 ± 7,7	27,5 ± 7,2
	Con endo 180° PT/BW	40 ± 10,9	43,5 ± 11,6	41,1 ± 14,5	45,1 ± 15,8
Post-testing	**Con exo 180° PT**	19,5 ± 8,1	20,4 ± 6,9	22,1 ± 8,1	22 ± 6,6
	Con endo 180° PT	27,3 ± 10,6	30,3 ± 11,1	31 ± 12,5	34,8 ± 13,4
	Ratio con ER/con IR 180°	71,8 ± 12,4	68,8 ± 9,7	73,8 ± 12,4	66,1 ± 11
	Con exo 180° PT/BW	28,1 ± 8,6	29,8 ± 7,8	29,6 ± 8,4	29,6 ± 6,2
	Con endo 180° PT/BW	39,4 ± 11,2	43,9 ± 11,2	41,4 ± 14	46,4 ± 13,7

Table 4: Descriptive statistics – concentric 180°/sec (PT, PT/BW, ratio)

			Control group		Intervention group	
			Non-dominant	**Dominant**	**Non-dominant**	**Dominant**
Pre-testing	**Work fatigue**	**Exo**	23 ±6,8	21,8 ±7,6	19,7 ± 13,1	24,1 ± 15
		Endo	17,8 ± 7,6	19,9 ± 9,4	7,5 ± 20,5	16,1 ± 10,2
Post-testing	**Work fatigue**	**Exo**	21 ± 9,8	22,3 ± 10,1	22,6 ± 10,9	21,3 ± 14,1
		Endo	11,5 ±19,2	20,1 ± 10,2	14,3 ± 8,4	15,1 ± 22,9

Table 5: Descriptive statistics - concentric 180°/sec (work first third, work last third, work fatigue)

		Control group		Intervention group	
		Non-dominant	**Dominant**	**Non-dominant**	**Dominant**
Pre-testing	**Con exo 240° PT**	17,3 ± 7	16,4 ± 6,4	18 ± 7,7	18,1 ± 5,6
	Con endo 240° PT	26,5 ± 10,1	27,7 ± 10,1	29,3 ± 12,5	31,2 ± 12,7
	Ratio con ER/con IR 240°	65,4 ± 11,1	59,8 ± 11,3	62,5 ± 11,4	61 ± 13
	Con exo 240° PT/BW	25 ± 7,6	23,8 ± 7,3	23,9 ± 7,9	24,3 ± 5,5
	Con endo 240° PT/BW	38,6 ± 11,6	40,5 ± 11,8	38,9 ± 13,5	41,6 ± 13,4
Post-testing	**Con exo 240° PT**	17,9 ± 7,1	18 ± 5,8	20 ± 7,6	19,6 ± 6,1
	Con endo 240° PT	25,6 ± 10,1	27,4 ± 10,2	29,4 ± 12,2	32,1 ± 13,1
	Ratio con ER/con IR 240°	69,0 ± 11,8	67,3 ± 9,8	69 ± 10,5	64,6 ± 14,4
	Con exo 240° PT/BW	25,8 ± 7,2	26,3 ± 6,4	26,8 ± 8	26,3 ± 5,7
	Con endo 240° PT/BW	37,7 ± 9,4	39,8 ± 10,3	39,3 ± 13,4	42,7 ± 13,7

Table 6: Descriptive statistics – concentric 240°/sec (PT, PT/BW, ratio)

			Control group		Intervention group	
			Non-dominant	**Dominant**	**Non-dominant**	**Dominant**
Pre-testing	**Work fatigue**	**Con exo 240°**	30,6 ± 13,7	25 ± 11	15,9 ± 17,1	14,4 ± 21,6
		Con endo 240°	18,6 ± 11,6	20,5 ± 11,2	8,6 ± 18,4	-3,6 ± 51,6
Post-testing	**Work fatigue**	**Con exo 240°**	28,6 ± 16,5	23,2 ± 12	17,5 ± 16,8	23 ± 14,1
		Con endo 240°	14,9 ± 12	15,5 ± 14,4	10,7 ± 22,6	14,4 ± 15,4

Table 7: Descriptive statistics – concentric 240°/sec (work first third, work last third, work fatigue)

		Control group		Intervention group	
		Non-dominant	Dominant	Non-dominant	Dominant
Pre-testing	**Ecc exo 30° PT**	22,1 ± 9,4	21,2 ± 8	23,9 ± 9,8	24,9 ± 8,1
	Ecc exo 30° PT/BW	31,8 ± 9,8	30,8 ± 8,4	31,8 ± 9,8	33,4 ± 7,9
	Ecc endo 30° PT	46,1 ± 16,4	48,1 ± 15,4	52,4 ± 23,7	56,3 ± 20,1
	Ecc endo 30° PT/BW	67,2 ± 18,7	70,3 ± 17,1	70,1 ± 25,8	75,6 ± 20,8
Post-testing	**Ecc exo 30° PT**	22,4 ± 8,6	22 ± 7,5	25,4 ± 9,5	25,3 ± 9,1
	Ecc exo 30° PT/BW	32,3 ± 8,8	31,9 ± 7,9	34 ± 9,8	33,9 ± 9,4
	Ecc endo30° PT	44,2 ± 15	46,2 ± 14	53,6 ± 21	56,1 ± 20,2
	Ecc endo 30° PT/BW	64,2 ± 14,4	67,2 ± 12,9	72 ± 22,3	75,3 ± 20,8

Table 8: Descriptive statistics – eccentric ER 30°/sec, eccentric IR 30°/sec (PT, PT/BW)

	Source	**Sign PT**	**Sign PT/BW**	**Sign Ratio ER/IR**	**Sign work fatigue**
Concentric exo 60°/sec	Time * Side * group	0.746	0.790	0.626	
	Time * Side	0.816	0.743	0.681	
	Time * Group	0.371	0.352	0.817	
	Side * Group	0.629	0.754	0.657	
	Time	0.054	**0.042**	**0.003**	
	Side	0.586	0.395	**0.001**	
	Group	0.490	0.929	0.326	
Concentric exo 180°/sec	Time * Side * group	0.095	0.074	0.115	0.121
	Time * Side	0.068	**0.036**	0.248	0.511
	Time * Group	0.236	0.208	0.743	0.796
	Side * Group	0.894	0.676	0.565	0.598
	Time	**0.009**	**0.007**	0.061	0.797
	Side	0.838	0.816	**<0.001**	0.563
	Group	0.489	0.985	0.792	0.972
Concentric exo 240°/sec	Time * Side * group	0.100	0.056	0.178	0.453
	Time * Side	0.635	0.538	0.840	0.418
	Time * Group	0.436	0.462	0.869	**0.046**
	Side * Group	0.731	0.728	0.783	0.105

	Time	**<0.001**	**<0.001**	**0.002**	0.346
	Side	0.486	0.764	**0.036**	0.426
	Group	0.486	0.967	0,712	**0.022**

Values in bold = p<0.05
Table 9: Main and interaction effects of concentric ER

	Source	**Sign PT**	**Sign PT/BW**	**Sign work fatigue**
Concentric endo 60°/sec	Time * Side * group	0.829	0.878	
	Time * Side	0.385	0.506	
	Time * Group	0.999	0.712	
	Side * Group	0.841	0.944	
	Time	0.136	0.141	
	Side	**<0.001**	**<0.001**	
	Group	0.288	0.561	
Concentric endo 180°/sec	Time * Side * group	0.984	0.983	0.173
	Time * Side	0.178	0.245	0.894
	Time * Group	0.811	0.618	0.088
	Side * Group	0.559	0.736	0.835
	Time	0.627	0.682	0.974
	Side	<0.001	<0.001	0.006
	Group	0.326	0.673	0.245
Concentric endo 240°/sec	Time * Side * group	0.996	0.756	0.217
	Time * Side	0,229	0.583	0.295
	Time * Group	0.441	0.433	0.005
	Side * Group	0.439	0.361	0.299
	Time	0.950	0.971	0.243
	Side	0.001	<0.001	0.567
	Group	0.325	0.704	0.111

Values in bold = p<0.05
Table 10: Main and interaction effects of concentric IR

	Source	Sign PT	Sign PT/BW
Eccentric exo 30°/sec	Time * Side * group	0.098	0.084
	Time * Side	0.465	0.387
	Time * group	0.673	0.721
	Side * group	0.335	0.313
	Time	0.161	0.150
	Side	0.828	0.988
	Group	0.298	0.580
Eccentric endo 30°/sec	Time * Side * group	0.464	0.402
	Time * Side	0.430	0.390
	Time * group	0.251	0.212
	Side * group	0.455	0.538
	Time	0.506	0.467
	Side	**0.003**	**0.001**
	Group	0.170	0.341

Values in bold = $p<0.05$
Table 11: Main and interaction effects of eccentric ER and IR

DISCUSSION

The main purpose of this study was to investigate whether a six weeks eccentric training program on the ER strength could improve the ER strength and the ratio con ER/con IR in healthy overhead athletes.

As main results of this single-blinded RCT, it is proven that con ER strength improved through time from pre- to post-testing. However, those differences cannot be attributed to the intervention. We can conclude that the intervention program has no effect on the con ER strength when compared to the control group. On the other hand, no pre- and post differences were seen in con IR strength. Only side differences were noticed. It can be said that an eccentric strength training program of the external rotators during a time laps of 6 weeks cannot influence the con IR strength. Besides the con ER and IR, which are insensitive for this sort of strength training program, also eccentric strength did not improve due to the intervention.

Remarkably, in both con ER and IR at 240°/s, post-testing work fatigue in the intervention group has increased when compared to the pre-testing measurements.

When resuming the data of the primary testing period, con ER at the dominant side does not differ significantly from the non-dominant side, while con IR at the dominant side is significantly higher than the non-dominant side. This corresponds with the results found in previous studies describing strength values in tennis and baseball players(9,10,20). These data expose the adaptations in rotator cuff strength and explain the muscular imbalance between ER and IR at the dominant side of these athletes, which is a well-known risk on developing shoulder injuries(5). In comparison with the testing after six weeks, all of the above mentioned similarities and differences were observed. The dominant and non-dominant relationships remained.

Ellenbecker & Davies (2000)(9) suggest an ER/IR ratio of approximately 66% to 75% to be normal. When looking at the pre-testing data of this study, we see at 60°/s percentages that are above (non-dominant side) or between (dominant side) the 66-75% interval Ellenbecker & Davies (2000) suggest. At 180°/s and 240°/s, all ER/IR ratios on the non-dominant side (except for the intervention group at 240°/s) lie within this region. Notable, ER/IR ratios on the dominant side at 180°/s and 240°/s are below 66%, while Ellenbecker & Davies (2000) report that the ER/IR ratio appears to remain the same throughout the velocity spectrum. This is remarkable because at 60°/s ratio appears to be normal. Participants performed five repetitions at 60°/s and 10 repetitions at 180°/s and 240°/s, thus a possible explanation could be fatigue or a limited endurance due to the fact that they were still in off-season or just started preparations for the new season.

Comparing the results of the re-testing with the original testing, the ER/IR ratios at the non-dominant side are still above the suggesting ratios at 60°/s(7). The dominant side in the control group increased to be also in between this interval. The dominant side of the intervention group stayed between the interval which has remained the same as exactly 6 weeks earlier.

At 180°/s, all ratios lie amongst the suggesting interval. This is also seen at 240°/s, except for the dominant side of the intervention group. With 64,6%, ER/IR ratio is lower than the suggested ratio.

For all these ER/IR ratios, there is an increase through time that can not be attributed to the intervention program. For ER, we have strength values that increase through time (also not distributed to the intervention program), while for IR this is not the case. This can partly explain the increase of the ratio. There is evidence that the ratio on the non-dominant side is always higher than the dominant side, at different testing speeds (60°/s, 180°/s and 240°/s). This is comparable with results found in previous studies(8,10).

The strength improvements of con ER through time can probably be accredited to the timing in the season. At the time they were tested, most participants had not restarted yet or had just started their training sessions after a recovery break. At the time of the second testing after six weeks, most of the participants had done a lot of strength training and regular sports training at their clubs, which could declare the time effect. However, training volume of normal strength training was not recorded for both groups, which should be acknowledged as a limitation. It is remarkable that the intervention group did not show more improvement than the control group after the six weeks training program and only con ER increased through time. This is contrasting in both con and ecc IR, where only side differences were observed. The strength training program consisted of eccentric ER exercises, but it was inevitable to completely exclude the con ER although both dominant and non-dominant sides were used for getting to the starting position. It is plausible that participants of the intervention group did not use their non-dominant side and only used their dominant side to get in starting position.

Participants of the intervention group only received ecc ER exercises of the dominant shoulder. Noticeably, ER strength of the non-dominant shoulder also increased through time. This could be possibly explained by the execution of the 1st exercise (seating/standing position) where the non-dominant shoulder was used as a counter force.

The patient compliance is equally important to be considered. The overhead athletes were asked to perform the exercises three times a week but there was no exact tool to record this disciplinary execution of the exercises. However, all patients received a personal logbook in which they confirmed performing the exercises three times a week, but there is still no guarantee of compliance.

Even though the distribution of both groups was randomly assigned, it is remarkable that the control group had an increased work fatigue pre-testing. After six weeks of training, the intervention group showed an increased work fatigue at 240°/s. In the control group post-testing, all results of work fatigue decreased. One possible explanation can be found in the timing of the execution of the exercises. Participants of the intervention group might have performed more exercises during the last week in order to compensate their less compliance during the first weeks. A late replacement of color of Thera Band could also be at the base of an increased work fatigue. Another possible explanation could be that participants are not acquainted to this kind of exercises, which could lead to extra fatigue. Moreover, they performed this training program in combination with their normal sport activities, which is more intense in pre-season than during competition period. When participants would have had a recovery week after the six weeks training program, the work fatigue could have decreased as well.

One important limitation of this single-blinded randomized controlled trial is the limited population that participated. Thirty-six overhead athletes, amongst which only 18 completing the strength training is a small representation of overhead athletes. Second remark: the athletes were practicing different sports, which makes it difficult to compare and to measure improvement since every sport has its own specific movements and biomechanics. Five basketball players and 6 korfball players were included in this study but their overhead movements are different from the other 5 overhead sports that were taken into account. The movement of basketball and korfball includes a shooting component. The movement needed in the other sports have a throwing or smashing component. Some overhead athletes perform their sports at high level, while others participate just for fun. A strength training program of only 6 weeks is also rather limited to have an improving effect on strength. Tubing bands have the advantage to do strength training on the field, but the subjective part can not be neglected. Athletes were advised to progress to more repetitions or another color of Thera Band when the 'feeling of discomfort' was no longer there. It is likely that some of the participants progressed too early or too late which can reduce the training effect. A too early or too late progression could be made when feeling sore after training or matches at their club and not necessarily because of the strength training with the Thera Band.

Future studies should focus on a higher amount of participants within a limited variety of sports. It is designated to perform the strength training more than six weeks. Participants might lower the work fatigue by giving them a rest week following an intense period of ER strength training. If the work fatigue can be decreased, ER strength could possibly improve more. Furthermore, it is advised to train in a more plyometric way, in order to extra load the external rotators of the dominant side. Further research is needed to investigate the role of eccentric ER training in the improvement of strength.

CONCLUSION

Con ER strength increased through time from pre to post-testing for both sides and both groups. These differences could not be distributed to the eccentric strength program of the intervention group. Concerning con IR strength, side differences were noticed between dominant and non-dominant shoulder. Those rates remained through time. Besides the con ER and IR that are insensitive for this training program, also eccentric strength did not improve due to the intervention. Due to an increase of con ER strength, con ER/IR ratio also increased through time. In both con ER and IR at 240°/s, intervention group had higher results post-testing for work fatigue. The conclusion is that the present study consisting of a six weeks eccentric ER strength training program has no effect on ER strength and con ER/con IR ratio.

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ABSTRACT IN LEKENTAAL

Bovenhandse sporters ondergaan unieke en repetitieve bewegingen waarbij hun schouders grote belastingen moeten ondergaan die kunnen leiden tot schouderblessures. Uit recente wetenschappelijke literatuur is gebleken dat verminderde kracht (naar buiten te bewegen van schouder en afremmen van beweging) en minder gunstige verhouding van stabiliserende spieren kunnen leiden tot een hoger letselrisico. Het doel van deze studie is om te onderzoeken welk effect een trainingsprogramma (trainen van afremmende kracht) heeft op de kracht van de stabiliserende spieren.

Willekeuring werden 36 gezonde proefpersonen ingedeeld in 2 groepen, een oefengroep en een controlegroep. Beide groepen ondergingen aan het begin van de studie een krachttesting. De oefengroep kreeg bovenop hun normale sportactiviteiten een 6 weken durend oefenprogramma dat bestond uit 3 verschillende oefeningen met een elastische rekker met toenemende weerstand en aantal herhalingen. Na 6 weken vond een hertesting plaats waarbij alle resultaten werden vergeleken.

Uit de resultaten bleek dat de kracht, die nodig is om de schouder naar buiten te bewegen, en de verhouding van de spieren in beide groepen gestegen is. Beide verbeteringen zijn dus niet gelinkt aan het oefenprogramma.

Deze studie toont aan dat het 6 weken durende oefenprogramma geen effect heeft op de kracht en verhouding tussen de stabiliserende spieren.

ATTACHMENTS

Attachment 1: Personal logbook intervention group

Week 1: / /2015

	Oefening in **ZIT**	Kleur	Pijn overdag/ tijdens	Oefening in **LIG**	Kleur	Pijn overdag/ tijdens	Oefening in **STAND**	Kleur	Pijn overdag/ tijdens
Maandag	3x10								
Dinsdag									
Woensdag									
Donderdag									
Vrijdag									
Zaterdag									
Zondag									

Week 2: / /2015

	Oefening in **ZIT**	Kleur	Pijn overdag/ tijdens	Oefening in **LIG**	Kleur	Pijn overdag/ tijdens	Oefening in **STAND**	Kleur	Pijn overdag/ tijdens
Maandag									
Dinsdag									
Woensdag									
Donderdag									
Vrijdag									
Zaterdag									
Zondag									

Week 3: / /2015

	Oefening in **ZIT**	Kleur	Pijn overdag/ tijdens	Oefening in **LIG**	Kleur	Pijn overdag/ tijdens	Oefening in **STAND**	Kleur	Pijn overdag/ tijdens
Maandag									
Dinsdag									
Woensdag									
Donderdag									
Vrijdag									
Zaterdag									
Zondag									

Week 4: / /2015

	Oefening in **ZIT**	Kleur	Pijn overdag/ tijdens	Oefening in **LIG**	Kleur	Pijn overdag/ tijdens	Oefening in **STAND**	Kleur	Pijn overdag/ tijdens
Maandag									
Dinsdag									
Woensdag									
Donderdag									
Vrijdag									
Zaterdag									
Zondag									

Week 5: / /2015

	Oefening in **ZIT**	Kleur	Pijn overdag/ tijdens	Oefening in **LIG**	Kleur	Pijn overdag/ tijdens	Oefening in **STAND**	Kleur	Pijn overdag/ tijdens
Maandag									
Dinsdag									
Woensdag									
Donderdag									
Vrijdag									
Zaterdag									
Zondag									

Week 6: / /2015

	Oefening in **ZIT**	Kleur	Pijn overdag/ tijdens	Oefening in **LIG**	Kleur	Pijn overdag/ tijdens	Oefening in **STAND**	Kleur	Pijn overdag/ tijdens
Maandag									
Dinsdag									
Woensdag									
Donderdag									
Vrijdag									
Zaterdag									
Zondag									

Attachment 2: Progression with elastic tube – intervention group

<table>
<tr><td rowspan="8">Progressie naar meer herhalingen of andere kleur theraband wanneer derde reeks geen brandend gevoel/ discomfort</td><th>AANTAL HERHALINGEN (3x/week)</th><th>KLEUR THERABAND</th><td rowspan="8">Volgorde theraband:
Geel = lichtste
Groen
Rood
Blauw
Zwart
Grijs
Goud = zwaarste

(Indien geen andere kleur ter beschikking, band dubbel nemen of korter nemen)</td></tr>
<tr><td>3x10</td><td>Toegewezen theraband</td></tr>
<tr><td>3x15</td><td>idem</td></tr>
<tr><td>3x20</td><td>idem</td></tr>
<tr><td>3x10</td><td>Nieuwe kleur theraband</td></tr>
<tr><td>3x15</td><td>idem</td></tr>
<tr><td>3x20</td><td>idem</td></tr>
<tr><td>…</td><td>Nieuwe kleur</td></tr>
</table>

Attachment 3: logbook

Persoonlijke gegevens	
Naam student	Aurélie DE RYCK Justine VANHAEVERMAET
Naam promotor	Prof. Dr. Ann Cools
Naam co-promotor	Prof. Dr. Ann Cools
Titel onderzoek	The effect of a six weeks eccentric training program on the shoulder external rotator strength and the rotator cuff strength ratio in healthy overhead athletes: a single-blinded randomized controlled trial

CONTACTMOMENT 1	
Datum+ uur	13 augustus 2015 – 9u
Aanwezigen	Dr. Annelies Maenhout – Justine Vanhaevermaet – Aurélie De Ryck
Verslag	– Uitleggen Biodex – Bespreken van testing procedure – Tonen startpositie – Programmatie computer
Op te volgen + deadlines	1. Testing van 14/08 tem 4/09

CONTACTMOMENT 2	
Datum+ uur	3 november 2015 – 9u
Aanwezigen	Allen aanwezig
Verslag	- Algemene bespreking testing augustus-september - Begin statistiek besproken – statistische procedures bespreken (soort analyse bespreken)
Op te volgen + deadlines	1. Gegevens in Excel zetten 2. Methode en inleiding beginnen schrijven

CONTACTMOMENT 3	
Datum+ uur	26 november 2015 – 9u
Aanwezigen	Allen aanwezig
Verslag	- Excelgegevens naar SPPS omzetten in juiste variabele - Uitleggen gem & standaarddeviatie - Antropometrische metingen in tabel - Normaalverdeling ahv histogram en 1 sample KS
Op te volgen + deadlines	TO DO → 7/12 1. Gegevens in SPSS controleren 2. Tabellen opstellen van gem+SD, antropometrische metingen 3. Normaalverdeling controleren

CONTACTMOMENT 4	
Datum+ uur	7 december 2015 – 9u30
Aanwezigen	Allen aanwezig
Verslag	- Bespreken antropometrische gegevens - Normaalverdeling bespreken - Uitleggen ANOVA - Uitleggen hoofd- en interactie-effecten
Op te volgen + deadlines	1. ANOVA testen uitvoeren 2. Schrijven statistische analyse (methode)

CONTACTMOMENT 5	
Datum+ uur	26 januari 2016 – 14u30
Aanwezigen	Allen aanwezig
Verslag	- Controleren ANOVA - Post hoc + Bonferroni uitleggen – gebruik + nut
Op te volgen + deadlines	1. Post hoc testen uitvoeren (naar workshops statistiek!) 2. Resultaten en Discussie schrijven