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# Shoulder range of motion in competitive tennis players: systematic review and meta-analysis



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#### A R T I C L E I N F O

Keywords: Tennis Shoulder Range of motion ROM Glenohumeral Rotation

*Level of evidence:* Basic Science Study; Kinesiology; Systematic Review **Background:** To compare shoulder range of motion (ROM) in dominant vs. nondominant shoulder of competitive tennis players, and to determine whether shoulder ROM is different between younger and older players, or males and females.

**Methods:** A search was performed on PubMed, Embase, and Epistemonikos on December 18, 2023. This study conforms to the principles of the Cochrane Collaboration and the Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines. Clinical studies or case reports on shoulder ROM including external rotation (ER; shoulder at 90° of abduction) and internal rotation (IR) in competitive, elite, or professional tennis players.

**Results:** We found 25 eligible studies that reported on a total of 18,534 tennis players, of which 20 studies reported the ROM for the dominant and nondominant side. Comparing dominant vs. nondominant shoulders revealed that dominant shoulders had significantly smaller IR ( $53.0^{\circ}$  vs.  $62.6^{\circ}$ ; P < .001). Comparing adults vs. children revealed that adults have significantly smaller IR ( $44.5^{\circ}$  vs.  $57.1^{\circ}$ ; P < .001) and ER ( $95.3^{\circ}$  vs.  $110.3^{\circ}$ ; P < .001). Comparing females vs. males revealed no significant differences in ER ( $113.4^{\circ}$  vs.  $104.9^{\circ}$ ; P = .360) or IR ( $54.3^{\circ}$  vs.  $56.4^{\circ}$ ; P = .710).

**Conclusion:** IR in shoulders of tennis players is significantly smaller in dominant vs. nondominant sides (53.0° vs. 62.6°, P < .001), and significantly smaller in adults vs. children (44.5° vs. 57.1°, P < .001). These findings could be relevant in the context of physical preparation and training of tennis players, to monitor evolution of IR as a result of their sport and/or as they transition from childhood to adulthood.

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Tennis is a sport in which players need to master a range of physical demands, such as agility, lower and upper body muscle strength, and endurance to reach peak performance.<sup>2,10,11</sup> Tennis also requires large shoulder range of motion (ROM), coupled with great forces to achieve high velocities.<sup>1,3,7,33,37</sup>

A number of studies suggested that the forces exerted through the shoulder of a tennis player could affect its ROM, notably decrease internal rotation (IR) and increase external rotation (ER).<sup>5,11-13,27,29,33</sup> Sport-specific adaptations in flexibility and strength of the glenohumeral joint may also result in shoulder pain in tennis players, due to the unilateral and repetitive nature of tennis, biomechanically overloading the upper extremity.<sup>20,21</sup> Furthermore, tennis players with a history of shoulder pain have decreased bilateral IR and total ROM,<sup>26</sup> but there might not be an association between shoulder ROM and risk of injury.<sup>32</sup> Finally, understanding the musculoskeletal shoulder ROM could assist in the development of injury prevention programs and advance the development of conditioning and rehabilitation programs.

Many clinical studies have investigated shoulder ROM in competitive tennis players; however, to the author's knowledge, this information has not yet been synthesized in a systematic review. Therefore, the purpose of this systematic review and metaanalysis is to compare shoulder ROM in dominant vs. nondominant shoulder of competitive tennis players, and to determine whether shoulder ROM is different between younger and older players, or males and females.

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Institutional review board approval was not required for this systematic review. This study was registered with PROSPERO, registration number CRD42022349108. \*Corresponding author: Floris van Rooij, MSc, ReSurg, Rue Saint-Jean 22 1260,

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#### Table I Included studies, demograph

Included studies, demographics, and instrumentation.

Author	Year	Country	Cohort					Hours played	per week?	Level of ex	perience	Instruments	
Journals			Overall	Sex		Age	BMI	Tennis	Conditioning	Practice	Level of	ROM type of measurement	
				ð	Ŷ	Mean $\pm$ SD		(h/week)	(h/week)	(y)	experience		
Reporting dominant and													
nondominant side													
López-Vidriero Tejedor	2023	Spain	270	78	57	22.1 ± 4.9	22.7	19.4 ± 4.9			ATP/WTA ranked (<1'000)	Goniometer	
KSSTA													
Tooth	2023	Belgium	24	24		<14							
J Sports Med Phys Fitness			17	17		14-18		15-20			International	Goniometer	
			12	12		>18					Tennis Number		
			13		13	<13					1-3		
			12		12	13-17							
			6		6	>17							
Fernandez-Fernandez	2022	Spain	13	13		$14.6 \pm 0.3$		$21.4 \pm 0.8$	$5.8 \pm 0.4$	$6.1 \pm 2.2$		Inclinometer (ISOMED	
J Strength Cond Res			13	13		$14.7 \pm 0.3$		$20.4 \pm 1.2$	$5.7 \pm 0.5$			inclinometer)	
Johansson	2022	Sweden	176	176		$14.4 \pm 2.0$	20.2	>8			National (50)	Smartphone inclinometer app	
Frontiers in Sports and Active Living			125		125	$14.6\pm2.0$	20.2				and regional (251)	(GetMyROM)	
Fllenbecker	2020	USA	92	92		256 + 36					Professionals	Digital inclinometer (Pro 3600	
OISM	2020	05/1	61	61		$25.0 \pm 3.0$ $26.9 \pm 3.9$					(ATP ranked)	SPI-Tronic)	
Fernandez-Fernandez	2020	Snain	12	12		$149 \pm 0.9$	199	8-10	2	$75 \pm 12$	(mir fanked)	Inclinometer (ISOMED	
Int. J. Environ. Res. Public	2020	Span	13	12	13	$14.5 \pm 0.9$ 14.5 ± 0.9	19.9	0-10	2	7.5 ± 1.2		inclinometer)	
Olivior	2020	Prozil	22			125 00	19.0			26,25		Digital inclinemator (Fab. Ent	
The Int L of Sports Phys Ther	2020	DI dZII	22			$12.3 \pm 0.9$	10.9			$3.0 \pm 2.3$		and Lafavotto Instr.)	
Fornandoz Fornandoz	2010	Spain	22	22		126 02	10 1	14 21		66 22		Inclingmenter (ISOMED	
	2019	Span	32	26		$12.0 \pm 0.2$ 146 ± 0.2	20.0	$14 \pm 5.1$		$0.0 \pm 3.2$		inclinometer)	
PLOS ONE			20	50	22	$14.0 \pm 0.3$ 12.6 ± 0.2	20.9					inclinometer)	
			22		32	$12.0 \pm 0.3$ $14.6 \pm 0.2$	19.2						
Cillet	2019	Franco	20	20	20	$14.0 \pm 0.3$ 11.5 + 2.0	20.5	06.70	25,16	61.25		Conjemeter	
Bhysical Thorapy in Sport	2018	France	30 61	30 61		$11.5 \pm 2.0$ $11.2 \pm 1.9$	17.2	$8.0 \pm 2.8$	$2.5 \pm 1.0$	$0.1 \pm 2.5$		Gomometer	
Physical merapy in Sport	2019	United Vingdom	60	101	62	$11.2 \pm 1.8$ 11.14	17.1	$8.3 \pm 2.3$	$2.4 \pm 1.7$	$6.2 \pm 2.2$		Conjemeter	
The Int Lof Sports Dhus Ther	2018	United Kingdom	69 56	122	02	11-14						Gomometer	
The fift J of Sports Phys Ther			50			14-16							
Dalmaa	2010	LICA	29 42	42		10-24					NTDD	Coniemeter	
	2018	USA	42	42		$23.9 \pm 5.8$				(4.5 - 6)	NIKP	Gomometer	
SPORIS HEALIH	2010		20	10	10	20.0				14 (7.24)		Disital is alia an aton (Missou	
Willidins Dhysical Thorapy in Sport	2018		30	18	12	20.0				14 (7-24)		WB260)	
Cillet	2017	Franco	26	26		87.07	15.0	65.22	11.17	41.11		(VKS00)	
Journal of Athletic Training	2017	ridice	20 21	20		$0.1 \pm 0.1$	15.9	$0.3 \pm 2.3$	$1.1 \pm 1.2$ 15 · 11	4.1 ± 1.1		Gomonieter	
journal of Athletic Training			21	21		$10.5 \pm 0.0$ $12.9 \pm 1.4$	10.5	$0.1 \pm 2.4$	$1.5 \pm 1.1$ 2.4 ± 1.9				
Moropo poroz	2015	Spain	20	20		$12.0 \pm 1.4$	17.1	$9.2 \pm 2.1$	$5.4 \pm 1.\delta$	50.20	lure of practice	Photograph (Capon IVI 1975	
Manual Thorany	2015	Spann	4/	47		$23.2 \pm 4.9$	23.0			$5.9 \pm 3.9$	162 Fel	digital camora)	
Goole	2014	Sweden	24	21	20		10.0	10.0			$10.2 \pm 3.0$ ]	uigital Calliera)	
Lournal of Athlatic Training	2014	Sweden	24	31	28 20.0	15.2	18.9	12.3				ACU260)	
Journal of Athletic Halling	22		12		20.0	13.5	24.4	15.6				ACU300)	
McConnell	2000	Australia	15	11		169.12	24.4	15.0			Elito junior	Conjometer	
Clip I Sport Mod	2009	AUSU dild	10	11	10	$10.0 \pm 1.3$ 140 + 0.9						Gomolleter	
Kowace	2007	LICA	0	0	10	$14.9 \pm 0.8$					(INSVVIS) Nationally	Conjomator	
NUVACS Br I Sports Mod	2007	USA	ð	ð							rapled NCAA	Gomometer	
DI J Sports Med Schmidt-Wiethoff	2004	Cermany	27	77		26 5 [10 22]				(10.22)	ATP rapled (1	3D real_time motion analysis	
Int I Sports Med	2004	Germany	21	21		20.3 [19-33]				(10-22)	to 02)	system (CMS 70D)	
int J Sports Med											to 93)	system (CMS 70P)	

Ellenbecker (a) Journal of Strength and Conditioning Research	2002	USA	11		11	19.2 ± 1.8			9.8 ± 2.0	Nationally ranked NCAA	Goniometer
Ellenbecker (b) Medicine & Science in Sports & Exercise	2002	USA	117	117		$16.4 \pm 1.6$				Arizona elite junior	Goniometer
Reporting only dominant side											
Le Solliec Front Sports Act Living	2023	France	22	18	4	16.0 ± 2.4	7.6 ± 2.4	$4.2\pm0.4$	9.8 ± 2.2	International Tennis Number 3-4	Goniometer
Martin AJSM	2016	France	8	8		20.4 ± 2.8				International tennis number (3-4)	Goniometer
Moore-reed The Int J of Sports Phys Ther	2016		79		79	$25.0\pm4.0$				Professionals	Inclinometer
Thomas Journal of Athletic Training	2009	USA	10		10	15.5 ± 1.1				High school (competitive)	Digital Inclinometer
Çolak	2004		21	21		27.6 ± 0.7	4 h/day (since 12-15 years)				Biodex System 3 (Biodex Medical Systems)
BJSM							- /				

SD, standard deviation; BMI, body mass index; ATP, Association of Tennis Professionals; WTA, Women's Tennis Association; NTRP, National Tennis Rating Program; NCAA, National Collegiate Athletic Association; ROM, range of motion.

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#### Materials and methods

The protocol for this systematic review was submitted to the International prospective register of systematic reviews (PROSPERO) prior to commencement (registration number CRD42022349108) and conforms to the principles outlined in the handbook of the Cochrane Collaboration,<sup>14</sup> along with the guidelines established by the Preferred Reporting Items for Systematic Reviews and Meta-analysis for which the required checklist was completed (see supplementary material).<sup>23</sup>

#### Search strategy

The authors conducted a structured electronic literature search on December 18, 2023 using the PubMed, Embase, and Epistemonikos databases, applying the keywords presented in Supplementary Appendix S1. The search was limited to articles published between January 1, 2001 and December 18, 2023, to ensure a contemporary systematic review. After removal of duplicate records, each of 2 researchers (T.C. and E.D.) screened the titles and abstracts to determine the suitability for the review using the following predefined eligibility criteria:

#### Inclusion criteria

 Comparative studies or case series on shoulder ROM (external/ internal rotation, forward elevation, abduction; measured using any method) in competitive, elite, or professional tennis players.

## Table II

Included studies, demographics, and range of motion.

Author	Year	Country	Cohort				Dominant			Nondominan	t	
Journals			Overall	Sex		Age	IR	ER	Total	IR	ER	Total
				ð	Ŷ	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	$Mean \pm SD$	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Lopez-Vidriero Tejedor KSSTA	2023	Spain	270	78	57	22.1 ± 4.9	51 ± 18	94 ± 9	145 ± 20	68 ± 17	93 ± 8	161 ± 19
Tooth	2023	Belgium	24	24		<14	$48 \pm 8$	$101 \pm 4$		$48 \pm 6$	97 ± 5	
J Sports Med Phys Fitness			17	17		14-18	$46 \pm 4$	98 ± 8		$50 \pm 6$	$95 \pm 6$	
			12	12		>18	$44 \pm 4$	$100 \pm 7$		$46 \pm 3$	$96 \pm 9$	
			13		13	<13	$46 \pm 6$	$101 \pm 5$		$46 \pm 6$	$98 \pm 5$	
			12		12	13-17	$50 \pm 7$	$100 \pm 6$		$51 \pm 9$	$100 \pm 7$	
			6		6	>17	$47 \pm 1$	$98 \pm 4$		$46 \pm 0$	97 ± 8	
Fernandez-Fernandez	2020	Spain	13	13		$14.6 \pm 0.3$	59 ± 8	$146 \pm 9$	$205 \pm 11$	$70 \pm 9$	$127 \pm 10$	198 ± 8
J Strength CondRes			13	13		$14.7 \pm 0.3$	58 ± 13	137 ± 11	$195 \pm 20$	77 ± 12	137 ± 16	$214 \pm 21$
Johansson	2022	Sweden	176	176		$14.4 \pm 2.0$	57 ± 12	98 ± 13	156 ± 17	65 ± 12	91 ± 13	157 ± 18
Frontiers in Sports and Active Living			125		125	$14.6 \pm 2.0$	62 ± 12	99 ± 13	$160 \pm 17$	72 ± 13	$94 \pm 13$	165 ± 17
Ellenbecker	2020	USA	92	92		$25.6 \pm 3.6$	37 ± 8	$100 \pm 8$	$136 \pm 10$	$46 \pm 7$	$94 \pm 13$	$142 \pm 8$
OJSM			61	61		$26.9 \pm 3.9$	38 ± 8	98 ± 9	$136 \pm 10$	$46 \pm 6$	$94 \pm 9$	$140 \pm 9$
Fernandez-Fernandez	2020	Spain	12	12		$14.9 \pm 0.9$	56 ± 13	$149 \pm 12$	$205 \pm 19$	$70 \pm 14$	$136 \pm 10$	$205 \pm 18$
Int. J. Environ. Res. Public Health			13		13	$14.5 \pm 0.9$	$59 \pm 10$	$153 \pm 14$	$212 \pm 19$	$68 \pm 14$	$137 \pm 14$	$206 \pm 20$
Olivier	2020	Brazil	22			$12.5 \pm 0.9$	$65 \pm 8$	$108 \pm 9$	$172 \pm 11$	$71 \pm 9$	$98 \pm 10$	$169 \pm 11$
The Int J of Sports Phys Ther												
Fernandez-Fernandez	2019	Spain	32	32		12.6 + 0.2	73 + 12	147 + 19	220 + 26	81 + 11	141 + 14	222 + 22
PLOS ONE		- <b>F</b>	36	36		$14.6 \pm 0.3$	62 + 14	$136 \pm 15$	198 + 23	78 + 11	$134 \pm 15$	212 + 20
			32		32	$12.6 \pm 0.3$	$67 \pm 14$	$140 \pm 18$	$207 \pm 26$	$80 \pm 18$	$140 \pm 12$	$220 \pm 24$
			28		28	$14.6 \pm 0.3$	$71 \pm 11$	$138 \pm 17$	$209 \pm 20$	$81 \pm 10$	$140 \pm 12$	$220 \pm 21$ $221 \pm 24$
Gillet	2018	France	30	30	20	$11.5 \pm 2.0$	$75 \pm 10$	86 + 8	$162 \pm 12$	80 + 8	85 + 8	165 + 13
Physical Therapy in Sport			61	61		$112 \pm 18$	$72 \pm 10$	83 + 9	$155 \pm 15$	$77 \pm 10$	$82 \pm 10$	$159 \pm 16$
Nutt	2018	United Kingdom	69	122	62	11-14	44 + 11	$103 \pm 8$	$100 \pm 10$ 147 + 12	$47 \pm 10$	$100 \pm 7$	$100 \pm 10$ 147 + 12
The Int L of Sports Phys Ther	2010	onneu ninguom	56		02	14-16	$38 \pm 10$	$103 \pm 0$ $107 \pm 9$	$146 \pm 12$	$45 \pm 10$	$100 \pm 7$ $102 \pm 8$	$148 \pm 12$
The fifty of sports rings fifter			59			16-24	$43 \pm 13$	$107 \pm 3$ $101 \pm 10$	$140 \pm 35$	$13 \pm 10$ 52 + 14	$97 \pm 10$	$138 \pm 34$
Palmer	2018	LISA	42	42		239 + 58	$13 \pm 13$ 52 ± 14	$97 \pm 13$	110 ± 55	$69 \pm 10$	$37 \pm 10$ $87 \pm 11$	150 ± 51
Sports Health	2010	05/1	-12	72		$23.5 \pm 3.0$	52 ± 14	57 ± 15		$05 \pm 10$	07 ± 11	
Williams	2018		30	18	12	20.0	53 + 9	$77 \pm 10$	$130 \pm 15$	$60 \pm 10$	$76 \pm 11$	$136 \pm 14$
Physical Therapy in Sport	2010		50	10	12	20.0	55 <u>+</u> 5	// <u>+</u> 10	150 ± 15	00 ± 10	70 <u>+</u> 11	150 ± 14
Cillet	2017	France	26	26		$87 \pm 0.7$	78 + 9	84 ± 9	$161 \pm 13$	81 + 0	83 + 6	$163 \pm 13$
Journal of Athletic Training	2017	Trance	20	20		$10.7 \pm 0.7$	$60 \pm 0$	$85 \pm 10$	$101 \pm 15$ $153 \pm 15$	$76 \pm 9$	$83 \pm 0$ $83 \pm 11$	$103 \pm 15$ 158 ± 15
Journal of Achieve Hanning			20	21		$10.5 \pm 0.0$ $12.8 \pm 1.4$	$66 \pm 9$	$83 \pm 10$ 83 ± 10	$135 \pm 15$ $149 \pm 16$	$70 \pm 3$ $74 \pm 11$	$35 \pm 11$ 70 ± 12	$150 \pm 15$ $154 \pm 17$
Morono poroz	2015	Spain	47	20		$12.0 \pm 1.4$	$46 \pm 12$	$01 \pm 0$	$145 \pm 10$ 126 ± 15	$74 \pm 11$	$75 \pm 12$	$1.34 \pm 1.7$ $1.42 \pm 1.5$
Manual Thorany	2015	Span	47	47		$23.2 \pm 4.9$	$40 \pm 12$	$51 \pm 5$	$150 \pm 15$	$39 \pm 12$	$04 \pm 0$	$142 \pm 13$
Cools	2014	Sweden	24	31	28		10 + 8	$104 \pm 7$	$154 \pm 9$	50 + 7	$100 \pm 5$	160 + 8
Journal of Athletic Training	2014	Sweden	24	21	20		$43 \pm 0$	$104 \pm 7$	$134 \pm 3$ $140 \pm 12$	59 ± 7	$100 \pm 3$	$100 \pm 3$ 157 ± 11
Journal of Adhetic Haining			12				$43 \pm 11$ $41 \pm 7$	$103 \pm 7$ 102 + 12	$149 \pm 12$ 142 + 11	$50 \pm 0$	$50 \pm 0$	$157 \pm 11$ 155 + 12
McCoppell	2000	Australia	15	11		169.12	$41 \pm 7$	$102 \pm 12$	$142 \pm 11$ 126 + 10	$50 \pm 9$	$100 \pm 11$ 01 + 10	$133 \pm 15$ $146 \pm 15$
Clip I Sport Mod	2009	Australia	10	11	10	$10.0 \pm 1.5$	$42 \pm 6$ 42 + 7	$94 \pm 10$	$130 \pm 10$ $125 \pm 14$	$55 \pm 7$	$91 \pm 10$	$140 \pm 15$ 142 + 0
Kauaaa	2007	LICA	10	00	10	$14.9 \pm 0.8$	$45 \pm 7$	$92 \pm 11$	$155 \pm 14$	$36 \pm 9$	$63 \pm 7$	$145 \pm 9$
KOVACS Dr. I. Smorthe Mod	2007	USA		88			$30 \pm 0$	91±7	$127 \pm 11$	$47 \pm 6$	87 ± 6	$134 \pm 9$
Br J Sports Med	2004	C	27	27		20 5 [10 22]	44 . 11	00 . 14	122 . 15	C1 , 7	01 . 10	142 . 12
Schinidt-Wietholi	2004	Germany	27	27		20.5 [19-33]	$44 \pm 11$	$89 \pm 14$	$133 \pm 15$	61 ± /	$81 \pm 10$	$142 \pm 12$
The points mea	2002	LICA	11		11	10.2 . 1.0	40 . 10	101 . 0	150	C1 . 0	05 . 6	150
Elieilbecker (d)	2002	USA	11		11	$19.2 \pm 1.8$	$49 \pm 10$	$101 \pm 9$	150	δ ± 10	95 ± 0	100
Journal of Strength and Conditioning Research	2002	LICA	117	117		104 . 10	45 . 14	104 . 11	140 . 10	50 . 12	102 . 11	150 . 10
Enendecker (D)	2002	USA	11/	11/		$10.4 \pm 1.0$	$45 \pm 14$	$104 \pm 11$	$149 \pm 18$	$50 \pm 12$	$102 \pm 11$	$100 \pm 10$
iviedicine & Science in Sports & Exercise												

SD, standard deviation; ER, external rotation; IR, internal rotation.

#### Table III

JBI checklist for analytical cross-sectional studies.

JBI, Joanna Briggs Institute.

#### Exclusion criteria

- Narrative or systematic reviews, noncomparative case series, expert opinions, editorials, letters to editors, case reports, or computer simulations.
- Studies published in languages other than English, French, German, or Spanish to avoid translation errors.

#### Study selection

Studies that met the eligibility criteria during title and abstract screening underwent full-text screening by 2 researchers (T.C. and E.D.) and any disagreement was first discussed between the researchers, and if required, a third researcher (F.V.R.) resolved any disagreement. The reference lists of studies for full-text review were searched, and an expert (J.G.) was consulted to identify further relevant studies that may not have been captured by the database searches.

#### Data extraction and quality assessment

Data extraction was performed by 2 researchers (T.C. and E.D.) independently and their results were compared to ensure accuracy. Where there was disagreement in the documented value, the true value was ascertained by simultaneous review of the data in question by both researchers. The following data were extracted from the included studies; author(s), journal, year of publication, level of evidence, country where study was performed, conflicts of interest, and funding declaration. Tennis player characteristics were retrieved, including group sizes, sex, age, hours of weekly training, and level of experience. The ROM including ER (shoulder at 90° of abduction) and IR were extracted as well as the type of instrument used. Methodological quality of the eligible studies was assessed by 2 researchers (T.C. and E.D.) according to the Joanna Briggs Institute checklist, to appraise the reporting quality (10 items).<sup>24</sup> Where there was disagreement between the researchers, consensus was achieved by discussion and review.

#### Statistical analysis

When available in the original articles, outcomes were tabulated: continuous outcomes were reported as means, standard deviations, and ranges, while categorical outcomes were reported as proportions. Heterogeneity was evaluated by visual inspection of forest plots, and using the l<sup>2</sup> statistic and its connected  $\chi^2$  test, to provide a measure of the degree of inconsistency across studies.<sup>15</sup> Pooled estimates of raw means and their 95% confidence interval (CI) were calculated using a random-effects model framework. Pooled estimates of proportions and their 95% Cls were calculated via Freeman-Tukey double arcsine transformation using inverse-variance weighting within a random-effects model framework. *P* values < .05 were considered statistically significant. Statistical analyses were performed using R version 4.1.3 (R Foundation for Statistical Computing, Vienna, Austria) using the Meta package.

#### Results

The systematic search returned 363 records, of which 137 were duplicates, leaving 226 for screening. A total of 171 studies were excluded by examining their titles and/or abstracts, and a further 25 studies were excluded after full-text review. This left 25 eligible studies that reported on a total of 1853 players (Table I, Fig. 1).<sup>4-13,</sup> <sup>16-19,21,22,25,27-30,33-36</sup> Of the 25 studies, 5 only reported the ROM for the dominant shoulders, while 20 studies reported the ROM for both dominant and nondominant shoulders (Table II). Of the 25 studies, 12 measured the ROM with a goniometer, 10 with an inclinometer, 1 using photographs, 1 using a motion analysis system, and 1 using a dynamometer (Table I).

#### Methodological quality

Quality assessment revealed that, of the 25 eligible studies, only 3 identified confounding factors (Table III). Furthermore, 6 of the included<sup>7,8,21,22,33,36</sup> studies did not clearly describe the study subjects and/or setting.

Study	Total	Mean	SD	IR	Mean	95% Cl	Weight
side = D				_			
Cools et al. 2014 – Between 14 and 16	22	43.4	11.3		43.4	[38.7; 48.1]	1.3%
Cools et al. 2014 – Over 16 years old	13	40.6	7.4		40.6	[36.6; 44.6]	1.3%
Cools et al. 2014 - Under 14 years old	24	49.4	10.2		49.4	[46.1; 52.7]	1.3%
Ellenbecker (b) et al. 2002 – Overall cohort	117	45.4	13.6		45.4	[42.9, 34.9]	1.2%
Ellenbecker et al. 2020 - With dominant-arm ISP atrophy	92	36.6	8.2		36.6	[35.0; 38.3]	1.3%
Ellenbecker et al. 2020 - Without dominant-arm ISP atrophy	/ 61	38.2	7.8	<b></b>	38.2	[36.2; 40.2]	1.3%
Fernandez et al. 2019 - Under 13 years old - F	32	67.1	14.1		67.1	[62.2; 72.0]	1.2%
Fernandez et al. 2019 – Under 13 years old – M	32	73.0	12.1		73.0	[68.8; 77.2]	1.3%
Fernandez et al. 2019 – Under 15 years old – F	28	71.0	10.5		71.0	[67.1; 74.9]	1.3%
Fernandez et al. 2019 - Under 15 years old - M Fernandez et al. 2020 - Refere Teppie, Projecto F	36	61.8	13.8		61.8	[57.3; 66.3]	1.3%
Fernandez et al. 2020 – Before Tennis, Pre-tests M	12	56.0	12.9		56.0	[48 7: 63 3]	1.2%
Fernandez-Fernandez et al. 2022 - PreControl	13	58.5	7.6		58.5	[54.4: 62.6]	1.3%
Fernandez-Fernandez et al. 2022 - PreTraining	13	58.0	13.0		58.0	[50.9; 65.1]	1.2%
Gillet et al. 2017 – AHPV–2	20	66.0	9.0		66.0	[62.1; 69.9]	1.3%
Gillet et al. 2017 – AHPV–3	21	69.0	9.0		69.0	[65.2; 72.8]	1.3%
Gillet et al. 2017 – AHPV–4	26	78.0	9.0		78.0	[74.5; 81.5]	1.3%
Gillet et al. 2018 – NHSP	30 61	72.0	10.0		72.0	[71.4; 78.6]	1.3%
Johansson et al. 2022 – All ages F	125	61.5	11.6		61.5	[59.5; 63.5]	1.3%
Johansson et al. 2022 – All ages M	176	57.2	12.2		57.2	[55.4; 59.0]	1.3%
Kovacs et al. 2007 - Pre (test)	8	35.9	6.2	+	35.9	[31.6; 40.2]	1.3%
López-Vidriero Tejedor et al. 2023	270	50.8	17.5		50.8	[48.7; 52.9]	1.3%
McConnell et al. 2009 - Female	10	43.2	7.2		43.2	[38.7; 47.7]	1.3%
McConnell et al. 2009 – Male	11	41.9	10.1		41.9	[37.3; 46.5]	1.3%
Nutt et al. 2018 – 14–15 vears old	47	45.0 38.0	10.0		45.0	[42.3; 49.3]	1.3%
Nutt et al. 2018 – Over 16 year old	59	43.0	13.0	-	43.0	[39.7: 46.3]	1.3%
Nutt et al. 2018 - Under 14 years old	69	44.0	11.0		44.0	[41.4; 46.6]	1.3%
Olivier et al. 2020 - mix	22	64.7	8.4	-	64.7	[61.2; 68.2]	1.3%
Palmer et al. 2018 - Overall cohort	42	51.8	14.4	_++	51.8	[47.4; 56.2]	1.3%
Schmidt-Wiethoff et al. 2004 - Tennis player	27	43.8	11.0		43.8	[39.7; 47.9]	1.3%
Tooth et al. 2023 – Prepubertal (<14)	24	47.6	7.6	-	47.6	[44.6; 50.7]	1.3%
Tooth et al. 2023 - Pubertal (14-18)	12	45.0	4.4		45.0	[43.5; 47.6]	1.3%
Tooth et al. $2023 - Prepubertal (<13)$	13	45.7	6.1		45.7	[42.4: 49.0]	1.3%
Tooth et al. 2023 – Pubertal (13–17)	12	49.6	7.1		49.6	[45.6; 53.6]	1.3%
Tooth et al. 2023 - Postpubertal (>17)	6	46.5	0.7	•	46.5	[45.9; 47.1]	1.3%
Williams et al. 2018 - Overall cohort	30	52.8	9.0		52.8	[49.6; 56.0]	1.3%
Random effects model	1713			\$	53.0	[49.3; 56.6]	50.7%
Heterogeneity: $T = 98\%$ , $\tau^{-} = 134.8615$ , $p = 0$							
side = ND							
Cools et al. 2014 - Between 14 and 16	22	58.1	7.9		58.1	[54.8; 61.4]	1.3%
Cools et al. 2014 – Over 16 years old	13	55.5	8.9		55.5	[50.7; 60.3]	1.2%
Cools et al. 2014 – Under 14 years old	24	59.4	6.5		59.4	[56.8; 62.0]	1.3%
Ellenbecker (a) et al. 2002 - Pre-season	11	60.8	8.5		60.8	[55.8; 65.8]	1.2%
Ellenbecker et al. 2020 – With dominant_arm ISP atrophy	92	46.3	6.9		46.3	[34.2, 30.4]	1.3%
Ellenbecker et al. 2020 – Without dominant–arm ISP atrophy	/ 61	46.0	6.3	+	46.0	[44.4: 47.5]	1.3%
Fernandez et al. 2019 - Under 13 years old - F	32	80.1	17.6		80.1	[74.0; 86.2]	1.2%
Fernandez et al. 2019 – Under 13 years old – M	32	81.3	11.0	-	81.3	[77.5; 85.2]	1.3%
Fernandez et al. 2019 – Under 15 years old – F	28	81.4	13.8		81.4	[76.3; 86.5]	1.2%
Fernandez et al. 2019 – Under 15 years old – M	36	77.6	10.8	_=	77.6	[74.1; 81.1]	1.3%
Fernandez et al. 2020 - Before Tennis, Pre-tests F	13	68.4	13.6		68.4	[61.0; 75.8]	1.2%
Fernandez-Fernandez et al. 2022 - PreControl	13	70.2	9.1		70.2	[65.3:75.1]	1.2%
Fernandez-Fernandez et al. 2022 - PreTraining	13	76.8	11.7		76.8	[70.4:83.2]	1.2%
Gillet et al. 2017 – AHPV–2	20	74.0	11.0		74.0	[69.2; 78.8]	1.3%
Gillet et al. 2017 – AHPV–3	21	76.0	9.0	-	76.0	[72.2; 79.8]	1.3%
Gillet et al. 2017 – AHPV–4	26	81.0	9.0		81.0	[77.5; 84.5]	1.3%
Gillet et al. 2018 – HSP Gillet et al. 2018 – NHSP	30	80.0	8.0		80.0	[7.1; 82.9]	1.3%
Gillet et al. 2018 - NHSP Johansson et al. 2022 - All agos F	61 10F	71 5	10.0		71.0 71.F	[/4.5; /9.5]	1.3%
Johansson et al. 2022 – All ages M	125	65.4	11.6		65.4	[63.7:67.1]	1.3%
Kovacs et al. 2007 – Pre (test)	., 5	46.5	5.8	-	46.5	[42.4; 50.6]	1.3%
López-Vidriero Tejedor et al. 2023	270	67.8	16.8	-+	67.8	[65.8; 69.8]	1.3%
McConnell et al. 2009 - Female	10	58.3	9.0		58.3	[52.7; 63.9]	1.2%
McConnell et al. 2009 - Male	11	55.0	7.4		55.0	[50.6; 59.4]	1.3%
Moreno-perez et al. 2015 - Overall cohort	47	58.6	11.8		58.6	[55.2; 62.0]	1.3%
Nutt et al. 2018 – 14–15 years old	56	45.0	10.0		45.0	[42.4; 47.6]	1.3%
Nutt et al. 2016 – Over 16 year old	60 29	02.0 47 ∩	14.0		02.0 47 ∩	[44 4· 40 6]	1.3%
Olivier et al. 2020 – mix	22	71.4	8.6		71.4	[67.8; 75.0]	1.3%
Palmer et al. 2018 – Overall cohort	42	69.2	10.0		69.2	[66.2; 72.2]	1.3%
Schmidt-Wiethoff et al. 2004 - Tennis player	27	60.8	7.4	+	60.8	[58.0; 63.6]	1.3%
Tooth et al. 2023 – Prepubertal (<14)	24	48.4	6.2	<b>1</b>	48.4	[45.9; 50.9]	1.3%
Iooth et al. 2023 – Pubertal (14–18)	17	49.8	5.8		49.8	[47.0; 52.5]	1.3%
Tooth et al. 2023 - Prostpubertal (>18)	12	40.3 AF F	3.5		46.3	[44.3; 48.2]	1.3%
Tooth et al. 2023 – Pubertal (13–17)	12	51.0	9.0		0.0 51 0	[45.9; 56 1]	1.2%
Tooth et al. 2023 – Postpubertal (>17)	6	46.0	0.0		46.0	[.0.0, 00.1]	0.0%
Williams et al. 2018 - Overall cohort	30	60.0	9.7	+	60.0	[56.5; 63.5]	1.3%
Random effects model	1713			$\diamond$	62.6	[58.7; 66.5]	49.3%
Heterogeneity: $I^{c} = 99\%$ , $\tau^{c} = 147.3233$ , $p = 0$							
Random effects model	3426			\$	57.7	[54.9; 60.6]	100.0%
Unterpresentation (2, 000) -2, 100,0501 - 0							

Heterogeneity:  $l^2 = 99\%$ ,  $\tau^2 = 162.2584$ , p = 0Test for subgroup differences:  $\chi_1^2 = 12.60$ , df = 1 (p < 0.01)

Figure 2 Forest plot comparing IR in dominant vs. nondominant side. The squares represent the mean values of the individual studies; the first and second diamonds represent the weighted means of the respective groups, and the third diamond represents the overall weighted mean, also shown using the *dotted lines*. *SD*, standard deviation; *CI*, confidence interval; *IR*, internal rotation.

20 40 60 80

Study	Total	Mean	SD	ER		Mean	95% C	Weight
side = D				<u> </u>				
Cools et al. 2014 – Between 14 and 16	22	105.1	6.5	-		105.1	[102.4; 107.8]	1.3%
Cools et al. 2014 – Over 16 years old	13	101.7	11.9	-		101.7	[ 95.2; 108.2]	1.2%
Cools et al. 2014 - Under 14 years old	24	104.4	0.5			104.4	[101.8; 107.0]	1.3%
Ellenbecker (b) et al. 2002 – FIE-Sedson	117	101.1	10.0			103.7	[95.7, 106.5]	1.2%
Ellenbecker et al. 2020 – With dominant–arm ISP atrophy	92	99.7	7.7			99.7	[98.1: 101.3]	1.3%
Ellenbecker et al. 2020 – Without dominant-arm ISP atrophy	61	97.7	9.0	+		97.7	[ 95.4; 99.9]	1.3%
Fernandez et al. 2019 – Under 13 years old – F	32	140.1	18.2			140.1	[133.8; 146.4]	1.2%
Fernandez et al. 2019 – Under 13 years old – M	32	146.6	18.5			146.6	[140.2; 153.0]	1.2%
Fernandez et al. 2019 – Under 15 years old – F	28	138.4	17.3			138.4	[132.0; 144.8]	1.2%
Fernandez et al. 2019 – Under 15 years old – M	36	136.4	14.6			136.4	[131.6; 141.2]	1.2%
Fernandez et al. 2020 – Before Tennis. Pre-tests F	13	152.5	13.8			152.5	[145.0; 160.0]	1.2%
Fernandez et al. 2020 - Before Tennis, Pre-tests M	12	149.4	12.3		-	149.4	[142.4; 156.4]	1.2%
Fernandez-Fernandez et al. 2022 - PreControl	13	136.8	11 1			136.8	[141.3, 150.9]	1.2%
Gillet et al. 2017 – AHPV-2	20	83.0	10.0			83.0	[78.6 87.4]	1.2%
Gillet et al. 2017 – AHPV–3	21	85.0	10.0			85.0	[ 80.7: 89.3]	1.2%
Gillet et al. 2017 - AHPV-4	26	84.0	9.0	+		84.0	[80.5; 87.5]	1.3%
Gillet et al. 2018 – HSP	30	86.0	8.0	+		86.0	[83.1;88.9]	1.3%
Gillet et al. 2018 – NHSP	61	83.0	9.0	*		83.0	[ 80.7; 85.3]	1.3%
Johansson et al. 2022 – All ages F	125	98.5	13.1	+		98.5	[ 96.2; 100.8]	1.3%
Johansson et al. 2022 – All ages M	176	98.4	12.5			98.4	[96.6; 100.2]	1.3%
Kovacs et al. 2007 – Pre (test)	070	90.9	6.7			90.9	[86.2; 95.5]	1.2%
McConnell et al. 2009 Eemale	2/0	93.0	10.0			93.0	[92.7, 94.9]	1.0%
McConnell et al. 2009 – Male	11	93.7	10.0			93.7	[87.8: 99.6]	1.2%
Moreno-perez et al. 2015 - Overall cohort	47	90.5	9.0	-		90.5	[87.9: 93.1]	1.3%
Nutt et al. 2018 - 14-15 years old	56	107.0	9.0	-		107.0	[104.6; 109.4]	1.3%
Nutt et al. 2018 – Over 16 year old	59	101.0	10.0	-		101.0	[ 98.4; 103.6]	1.3%
Nutt et al. 2018 – Under 14 years old	69	103.0	8.0			103.0	[101.1; 104.9]	1.3%
Olivier et al. 2020 – mix	22	107.6	9.4			107.6	[103.7; 111.5]	1.3%
Palmer et al. 2018 – Overall cohort	42	97.1	13.3	-+-		97.1	[ 93.1; 101.1]	1.3%
Schmidt-Wiethoff et al. 2004 - Tennis player	27	89.1	13.7			89.1	[83.9; 94.3]	1.2%
Tooth et al. 2023 – Prepubertal (<14)	24	101.0	4.2			101.0	[99.3; 102.7]	1.3%
Tooth et al. 2023 – Pubertal (14–18)	12	98.3	7.8			100.4	[94.6; 102.0]	1.3%
Tooth et al. 2023 – Prepubertal (<13)	13	101.1	5.2			101.1	[98.3:104.0]	1.3%
Tooth et al. 2023 – Pubertal (13–17)	12	100.1	6.4			100.1	[ 96.5: 103.7]	1.3%
Tooth et al. 2023 - Postpubertal (>17)	6	98.0	3.6	+		98.0	[95.1; 100.9]	1.3%
Williams et al. 2018 - Overall cohort	30	77.1	10.0	+		77.1	[73.5; 80.7]	1.3%
Random effects model	1713			<b></b>		105.4	[ 99.0; 111.7]	50.0%
Heterogeneity: $l^2 = 98\%$ , $\tau^2 = 410.2293$ , $p = 0$								
and the second s								
Side = ND Cools at al. 2014 Between 14 and 16	22	08.4	70			08.4	[ 05 1: 101 7]	1 2%
Cools et al. 2014 - Detween 14 and 16	13	90.4	11.0			90.4	[93.1, 101.7]	1.0%
Cools et al. 2014 – Under 14 years old	24	100.0	5.3	-		100.0	[ 97.9: 102.1]	1.3%
Ellenbecker (a) et al. 2002 - Pre-season	11	95.3	6.4	+		95.3	[91.5; 99.0]	1.3%
Ellenbecker (b) et al. 2002 - Overall cohort	117	101.8	10.8			101.8	[99.8; 103.8]	1.3%
Ellenbecker et al. 2020 - With dominant-arm ISP atrophy	92	93.9	13.5	-+-		93.9	[91.1; 96.6]	1.3%
Ellenbecker et al. 2020 - Without dominant-arm ISP atrophy	61	94.1	8.7	+		94.1	[91.9; 96.3]	1.3%
Fernandez et al. 2019 – Under 13 years old – F	32	140.0	11.9			140.0	[135.8; 144.1]	1.3%
Fernandez et al. 2019 – Under 13 years old – M	32	140.7	14.1			140.7	[135.8; 145.6]	1.2%
Fernandez et al. 2019 - Under 15 years old - F	28	140.0	15.0			140.0	[134.4; 145.6]	1.2%
Fernandez et al. 2019 - Onder 15 years old - M	12	134.5	12.0			134.5	[129.5, 139.5]	1.2%
Fernandez et al. 2020 – Before Tennis, Pre-tests M	12	135.7	10.2		-	135.7	[129.9: 141.5]	1.2%
Fernandez-Fernandez et al. 2022 - PreControl	13	127.3	9.5		-	127.3	[122.1: 132.5]	1.2%
Fernandez-Fernandez et al. 2022 - PreTraining	13	136.9	15.7			136.9	[128.4; 145.4]	1.2%
Gillet et al. 2017 – AHPV–2	20	79.0	12.0	+		79.0	[73.7; 84.3]	1.2%
Gillet et al. 2017 – AHPV–3	21	83.0	11.0	-+-		83.0	[78.3; 87.7]	1.2%
Gillet et al. 2017 – AHPV–4	26	83.0	6.0	+		83.0	[ 80.7; 85.3]	1.3%
Gillet et al. 2018 – HSP	30	85.0	8.0	+		85.0	[82.1; 87.9]	1.3%
Gillet et al. 2018 – NHSP	61	82.0	10.0			82.0	[ 79.5; 84.5]	1.3%
Johansson et al. 2022 - All ages F	125	93.5	12.5			93.5	[91.3; 95.7]	1.3%
Kovacs of al. 2007 Pro (tost)	1/0	91.3	6.2			91.3	[ 09.4; 93.2]	1.3%
Lónez-Vidriero Tejedor et al. 2023	270	93.4	8.4			93.4	[92.4: 94.4]	1.2%
McConnell et al. 2009 - Female	10	84.5	7.1			84.5	[ 80.1: 88.9]	1.2%
McConnell et al. 2009 - Male	11	90.7	10.2	-+-		90.7	[84.7; 96.7]	1.2%
Moreno-perez et al. 2015 - Overall cohort	47	84.2	7.7			84.2	[82.0;86.4]	1.3%
Nutt et al. 2018 – 14–15 years old	56	102.0	8.0	-		102.0	[ 99.9; 104.1]	1.3%
Nutt et al. 2018 – Over 16 year old	59	97.0	10.0	+		97.0	[94.4; 99.6]	1.3%
Nutt et al. 2018 – Under 14 years old	69	100.0	7.0	-		100.0	[98.3; 101.7]	1.3%
Olivier et al. 2020 – mix	22	98.0	10.5			98.0	[93.6; 102.4]	1.2%
Famer et al. 2018 - Overall conort Schmidt, Wiethoff et al. 2004 - Toppie playor	42	8/.3	10.5			8/.3	[ 84.1; 90.5]	1.3%
Tooth et al. 2023 – Prepubertal (<14)	2/ 2/	965	4.6			96 5	[94.7.09.0]	1.3%
Tooth et al. 2023 – Pubertal (14–18)	17	95.0	5.9			95.0	[92.2 97.8]	1.3%
Tooth et al. 2023 – Postpubertal (>18)	12	95.8	9.4			95.8	[ 90.4; 101.1]	1.2%
Tooth et al. 2023 – Prepubertal (<13)	13	98.0	5.0	-+		98.0	[ 95.3; 100.7]	1.3%
Tooth et al. 2023 – Pubertal (13–17)	12	100.4	6.6			100.4	[96.6; 104.1]	1.3%
Tooth et al. 2023 - Postpubertal (>17)	6	97.3	7.5	+		97.3	[91.3; 103.3]	1.2%
Williams et al. 2018 - Overall cohort	30	76.0	10.7			76.0	[72.2; 79.8]	1.3%
Random effects model	1713			\$		100.8	[ 94.9; 106.7]	50.0%
Heterogeneity: $I^{-} = 99\%$ , $\tau^{-} = 361.8601$ , $p = 0$								
Bandom effects model	3426					103 1	[ 98 7. 107 41	100.0%
Heterogeneity: $l^2 = 99\%$ $\tau^2 = 386.2268$ n - 0	3420		1			103.1	[ 30.7, 107.4]	100.0%
Test for subgroup differences: $\chi_1^2 = 1.06$ , $df = 1$ ( $p = 0.30$ )			2	40 60 80 100 120	0 140 16	0		

Figure 3 Forest plot comparing ER in dominant vs. nondominant side. SD, standard deviation; CI, confidence interval; ER, external rotation.

Study	Total	Mean	SD		٦	гот		Mean	95%	CI Weight
side = D										
Johansson et al. 2022 – All ages M	176	155.6	17.4			÷.,		155.6	[153.0; 158.	2] 1.6%
Johansson et al. 2022 – All ages F	125	160.0	17.0					160.0	[157.0; 163.	0] 1.6%
Ellenbecker et al. 2020 – With dominant-arm ISP atrophy	92	136.3	10.5			•		136.3	[134.2; 138	5] 1.6%
Ellenbecker et al. 2020 - Without dominant-arm ISP atrophy	61	135.9	9.6					135.9	[133.5; 138.	3] 1.6%
Fernandez et al. 2020 - Before Tennis. Pre-tests M	12	205.4	19.4					205.4	[194.4; 216.	4] 1.5%
Fernandez et al. 2020 - Betore Tennis. Pre-tests F	13	211.6	18.9					211.6	[201.3; 221.	9] 1.5%
Olivier et al. 2020 – mix	22	1/2.3	11.2					1/2.3	[167.7; 177.	0] 1.6%
Fernandez et al. 2019 - Under 13 years old - M	32	219.6	26.3					219.6	[210.4; 228	/] 1.5%
Fernandez et al. 2019 - Under 15 years old - M	30	198.2	23.4					198.2	[190.5; 205	9] 1.6%
Fernandez et al. 2019 – Onder 15 years old – F	20	207.1	20.0					207.1	[201 2:217	6] 1.5%
Gillet et al. 2019 – Onder 15 years old – 1	20	162.0	12.0			i di seconda		162.0	[167 7: 166	21 1.6%
Gillet et al. 2018 NHSP	61	155.0	15.0					155.0	[151.2:158	8] 1.6%
Nutt et al. 2018 – Under 14 years old	69	147.0	12.0					147.0	[144 2: 149	8] 1.6%
Nutt et al. 2018 - 14-15 years old	56	146.0	12.0					146.0	[142 9: 149	11 1.6%
Nutt et al. 2018 - Over 16 year old	59	140.0	35.0			<b>.</b>		140.0	[131.1: 148	9] 1.5%
Williams et al. 2018 - Overall cohort	30	129.9	15.1					129.9	[124.5: 135.	3] 1.6%
Gillet et al. 2017 - AHPV-4	26	161.0	13.0			÷.		161.0	[156.0: 166.	0 1.6%
Gillet et al. 2017 - AHPV-3	21	153.0	15.0					153.0	[146.6: 159	4] 1.6%
Gillet et al. 2017 – AHPV-2	20	149.0	16.0					149.0	[142.0; 156	0 1.6%
Moreno-perez et al. 2015 - Overall cohort	47	136.2	15.4					136.2	[131.8; 140.	6 1.6%
Cools et al. 2014 - Under 14 years old	24	153.8	9.1			-+-		153.8	[150.2; 157	4] 1.6%
Cools et al. 2014 - Between 14 and 16	22	148.6	12.4			-+-		148.6	[143.4; 153.	8] 1.6%
Cools et al. 2014 - Over 16 years old	13	142.3	11.0					142.3	[136.3; 148.	3] 1.6%
McConnell et al. 2009 - Male	11	135.6	10.1			-		135.6	[129.6; 141.	6] 1.6%
McConnell et al. 2009 - Female	10	135.0	13.5			+		135.0	[126.6; 143.	4] 1.5%
Kovacs et al. 2007 - Pre (test)	8	126.8	11.2					126.8	[119.0; 134	5] 1.6%
Schmidt-Wiethoff et al. 2004 - Tennis player	27	132.9	15.0					132.9	[127.2; 138.	6] 1.6%
Ellenbecker (a) et al. 2002 - Pre-season	11	150.0						150.0		0.0%
Ellenbecker (b) et al. 2002 – Overall cohort	117	149.1	18.4			-		149.1	[145.8; 152	4] 1.6%
López-Vidriero Tejedor et al. 2023	270	144.5	20.2			•		144.5	[142.1; 146.	9] 1.6%
Fernandez-Fernandez et al. 2022 - PreControl	13	204.6	11.1				-	204.6	[198.6; 210.	6] 1.6%
Fernandez-Fernandez et al. 2022 - PreTraining	13	194.8	20.4					194.8	[183.7; 205.	9] 1.5%
Random effects model	1587							161.0	[151.2; 170.	8] 50.0%
Heterogeneity: $I^{2} = 99\%$ , $\tau^{2} = 788.6899$ , $p = 0$										
side = ND	170	156.7	177					150.7	1154 1. 150	01 1 00/
Johansson et al. 2022 – All ages M	1/0	165.0	17.0			1.1		100.7	[154.1; 159.	0] 1.0%
Ellenhocker et al. 2022 - All dyes F	120	141 5	0.2					141 5	[102.0, 100.	0] 1.0%
Elephecker et al. 2020 – With dominant arm ISP atrophy	61	141.5	0.5					141.5	[137.7.143	2] 1.0% 5] 1.6%
Energendez et al. 2020 - Without dominant-ann ISF all ophy	12	205.2	19.0					205.2	[105.0:215	/] 1.0%
Fernandez et al. 2020 - Before Tennis, Pre-tests K	13	205.2	20.2				-	205.2	[104 7: 216	7] 1.5%
Olivier et al. 2020 – mix	22	169.4	11.2					169.4	[164 7: 174	11 1.6%
Fernandez et al. 2019 – Under 13 years old – M	32	222.0	21.6					222.0	[214 5: 229	5] 1.6%
Fernandez et al. 2019 - Under 15 years old - M	36	212.1	20.0				- 65	212.1	[205 6: 218	6] 1.6%
Fernandez et al. 2019 - Under 13 years old - F	32	220.1	24.0					220.1	[211.7: 228	4] 1.5%
Fernandez et al. 2019 - Under 15 years old - F	28	221.4	24.1				-	221.4	[212.5: 230	3] 1.5%
Gillet et al. 2018 – HSP	30	165.0	13.0				_	165.0	[160.3: 169.	71 1.6%
Gillet et al. 2018 - NHSP	61	159.0	16.0			-		159.0	[155.0; 163.	01 1.6%
Nutt et al. 2018 – Under 14 years old	69	147.0	12.0					147.0	144.2: 149	81 1.6%
Nutt et al. 2018 - 14-15 years old	56	148.0	12.0			+		148.0	[144.9: 151.	1] 1.6%
Nutt et al. 2018 – Over 16 year old	59	138.0	34.0			+		138.0	[129.3; 146	7] 1.5%
Williams et al. 2018 - Overall cohort	30	136.0	14.1					136.0	[131.0; 141.	0] 1.6%
Gillet et al. 2017 – AHPV-4	26	163.0	13.0			-+		163.0	[158.0; 168.	0] 1.6%
Gillet et al. 2017 – AHPV–3	21	158.0	15.0			-+-		158.0	[151.6; 164.	4] 1.6%
Gillet et al. 2017 – AHPV–2	20	154.0	17.0					154.0	[146.5; 161	5] 1.6%
Moreno-perez et al. 2015 - Overall cohort	47	142.3	15.0					142.3	[138.0; 146	6] 1.6%
Cools et al. 2014 – Under 14 years old	24	159.5	8.2			+-		159.5	[156.2; 162.	8] 1.6%
Cools et al. 2014 – Between 14 and 16	22	156.5	10.9					156.5	[151.9; 161.	1] 1.6%
Cools et al. 2014 – Over 16 years old	13	155.1	13.2					155.1	[147.9; 162	3] 1.6%
McConnell et al. 2009 – Male	11	145.7	14.6			-+-		145.7	[137.1; 154.	3] 1.5%
McConnell et al. 2009 – Female	10	142.8	9.4					142.8	[137.0; 148	6] 1.6%
Kovacs et al. 2007 - Pre (test)	8	133.5	9.3					133.5	[127.0; 140.	0] 1.6%
Schmidt-Wiethoff et al. 2004 - Tennis player	27	142.0	11.9					142.0	[137.5; 146.	5] 1.6%
Ellenbecker (a) et al. 2002 - Pre-season	11	156.1				13		156.1	1455 Q 451	0.0%
Ellenbecker (b) et al. 2002 - Overall cohort	117	158.2	15.9					158.2	[155.3; 161.	1] 1.6%
Lopez-vidriero Tejedor et al. 2023	270	161.2	18.9					161.2	[158.9; 163.	5] 1.6%
Fernandez – Fernandez et al. 2022 – PreControl	13	197.5	0.1					197.5	[193.1; 201.	9] 1.0% 9] 4.5%
Pandom offosts model	1597	213.8	21.1			~		∠13.8 166 =	[202.3; 225.	oj 1.0% 21 50.0%
Hotorogonality: $l^2 = 90\%$ , $z^2 = 797,3292$ , $p = 0$	100/					<b>\$</b>		6.001	[100.6; 1/6.	J JU.U%
$received on 0.01, r = 33\%, \tau = ror.3282, p = 0$										
Bandom effects model	3174					6		163.8	[156.9: 170	7] 100 0%
Heterogeneity: $l^2 = 99\%$ , $\tau^2 = 783.0495$ . $p = 0$	5.74				1	- Ť	1	00.0	1.00.0, 170.	//
Test for subgroup differences: $\chi_1^2 = 0.61$ , df = 1 (p = 0.43)				50	100	150	200	250		

Figure 4 Forest plot comparing total ROM in dominant vs. nondominant side. SD, standard deviation; CI, confidence interval; ROM, range of motion.

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Study	Total	Mean	SD		IF	8	Mean	95% CI	Weight
age = older						÷			
Cools et al. 2014 – Over 16 years old	13	40.6	7.4				40.6	[36.6: 44.6]	2.5%
Ellenbecker (a) et al. 2002 - Pre-season	11	48.9	10.2			<u>:</u>	48.9	[42.9; 54.9]	2.4%
Ellenbecker et al. 2020 – With dominant-arm ISP atrophy	92	36.6	8.2		+		36.6	[35.0; 38.3]	2.6%
Ellenbecker et al. 2020 – Without dominant-arm ISP atrophy	61	38.2	7.8				38.2	[36.2; 40.2]	2.6%
Kovacs et al. 2007 – Pre (test)	8	35.9	6.2			-	35.9	[31.6: 40.2]	2.5%
López-Vidriero Teiedor et al. 2023	270	50.8	17.5		-		50.8	[48.7: 52.9]	2.5%
Moreno-perez et al. 2015 - Overall cohort	47	45.8	12.1				45.8	[42.3; 49.3]	2.5%
Nutt et al. 2018 – Over 16 year old	59	43.0	13.0				43.0	[39.7; 46.3]	2.5%
Palmer et al. 2018 – Overall cohort	42	51.8	14.4			+	51.8	[47.4; 56.2]	2.5%
Schmidt–Wiethoff et al. 2004 – Tennis player	27	43.8	11.0			-	43.8	[39.7; 47.9]	2.5%
Tooth et al. 2023 – Postpubertal (>18)	12	44.4	3.9		-+-		44.4	[42.2; 46.6]	2.5%
Tooth et al. 2023 – Postpubertal (>17)	6	46.5	0.7		+		46.5	[45.9; 47.1]	2.6%
Williams et al. 2018 - Overall cohort	30	52.8	9.0				52.8	[49.6; 56.0]	2.5%
Random effects model	678				$\diamond$		44.5	[41.4; 47.5]	32.7%
Heterogeneity: $I^2 = 95\%$ , $\tau^2 = 28.8967$ , $p < 0.01$						- - - -		la / sl	
age = younger						-			
Cools et al. 2014 – Between 14 and 16	22	43.4	11.3				43.4	[38.7; 48.1]	2.5%
Cools et al. 2014 – Under 14 years old	24	49.4	8.2			-	49.4	[46.1; 52.7]	2.5%
Ellenbecker (b) et al. 2002 – Overall cohort	117	45.4	13.6		-		45.4	[42.9: 47.9]	2.5%
Fernandez et al. 2019 – Under 13 years old – F	32	67.1	14.1				67.1	[62.2; 72.0]	2.5%
Fernandez et al. 2019 – Under 13 years old – M	32	73.0	12.1				- 73.0	[68.8; 77.2]	2.5%
Fernandez et al. 2019 – Under 15 years old – F	28	71.0	10.5				71.0	[67.1; 74.9]	2.5%
Fernandez et al. 2019 – Under 15 years old – M	36	61.8	13.8				61.8	[57.3; 66.3]	2.5%
Fernandez et al. 2020 – Before Tennis. Pre-tests F	13	59.1	10.2				59.1	[53.6; 64.6]	2.4%
Fernandez et al. 2020 – Before Tennis. Pre-tests M	12	56.0	12.9		_		56.0	[48.7; 63.3]	2.3%
Fernandez–Fernandez et al. 2022 – PreControl	13	58.5	7.6				58.5	[54.4; 62.6]	2.5%
Fernandez-Fernandez et al. 2022 - PreTraining	13	58.0	13.0				58.0	[50.9; 65.1]	2.3%
Gillet et al. 2017 – AHPV–2	20	66.0	9.0			-+-	66.0	[62.1; 69.9]	2.5%
Gillet et al. 2017 – AHPV–3	21	69.0	9.0			-+-	69.0	[65.2; 72.8]	2.5%
Gillet et al. 2017 – AHPV–4	26	78.0	9.0				+ 78.0	[74.5; 81.5]	2.5%
Gillet et al. 2018 – HSP	30	75.0	10.0			-	- 75.0	[71.4; 78.6]	2.5%
Gillet et al. 2018 – NHSP	61	72.0	10.0				72.0	[69.5; 74.5]	2.5%
Johansson et al. 2022 – All ages F	125	61.5	11.6				61.5	[59.5; 63.5]	2.6%
Johansson et al. 2022 – All ages M	176	57.2	12.2			+	57.2	[55.4; 59.0]	2.6%
McConnell et al. 2009 – Female	10	43.2	7.2				43.2	[38.7; 47.7]	2.5%
McConnell et al. 2009 – Male	11	41.9	7.7			-	41.9	[37.3; 46.5]	2.5%
Nutt et al. 2018 – 14–15 years old	56	38.0	10.0		-+		38.0	[35.4; 40.6]	2.5%
Nutt et al. 2018 – Under 14 years old	69	44.0	11.0				44.0	[41.4; 46.6]	2.5%
Olivier et al. 2020 – mix	22	64.7	8.4				64.7	[61.2; 68.2]	2.5%
Tooth et al. 2023 – Prepubertal (<14)	24	47.6	7.6		-+		47.6	[44.6; 50.7]	2.5%
Tooth et al. 2023 – Pubertal (14–18)	17	45.6	4.4			-	45.6	[43.5; 47.6]	2.5%
Tooth et al. 2023 – Prepubertal (<13)	13	45.7	6.1			-	45.7	[42.4; 49.0]	2.5%
Tooth et al. 2023 – Pubertal (13–17)	12	49.6	7.1		- +	:	49.6	[45.6; 53.6]	2.5%
Random effects model	1035					$\diamond$	57.1	[52.6; 61.6]	67.3%
Heterogeneity: $l^2 = 98\%$ , $\tau^2 = 136.2238$ , $p < 0.01$						-			
Random effects model	1713				<	>	53.0	[49.3; 56.6]	100.0%
Heterogeneity: $I^2 = 98\%$ , $\tau^2 = 134.8615$ , $p = 0$							I		
Test for subgroup differences: $\chi_1^2 = 20.78$ , df = 1 ( $p < 0.01$ )				20	40	60	80		

Figure 5 Forest plot comparing IR in older vs. younger tennis players. SD, standard deviation; CI, confidence interval; IR, internal rotation.

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Study	Total	Mean	SD	E	R	Mean	95% CI	Weight
age = older								
Cools et al. 2014 - Over 16 years old	13	101.7	11.9			101.7	[ 95.2: 108.2]	2.5%
Ellenbecker (a) et al. 2002 - Pre-season	11	101.1	9.1			101.1	[ 95.7; 106.5]	2.5%
Ellenbecker et al. 2020 – With dominant-arm ISP atrophy	92	99.7	7.7		+	99.7	[ 98.1: 101.3]	2.5%
Ellenbecker et al. 2020 – Without dominant-arm ISP atrophy	61	97.7	9.0		+	97.7	[95.4; 99.9]	2.5%
Kovacs et al. 2007 – Pre (test)	8	90.9	6.7	-		90.9	[ 86.2; 95.5]	2.5%
López-Vidriero Tejedor et al. 2023	270	93.8	9.3		+	93.8	[92.7; 94.9]	2.5%
Moreno-perez et al. 2015 - Overall cohort	47	90.5	9.0	+		90.5	[87.9; 93.1]	2.5%
Nutt et al. 2018 – Over 16 year old	59	101.0	10.0		+	101.0	[ 98.4; 103.6]	2.5%
Palmer et al. 2018 - Overall cohort	42	97.1	13.3		-+-	97.1	[ 93.1; 101.1]	2.5%
Schmidt-Wiethoff et al. 2004 - Tennis player	27	89.1	13.7	+	-	89.1	[83.9; 94.3]	2.5%
Tooth et al. 2023 – Postpubertal (>18)	12	100.4	7.1		+	100.4	[96.4; 104.4]	2.5%
Tooth et al. 2023 – Postpubertal (>17)	6	98.0	3.6		+	98.0	[ 95.1; 100.9]	2.5%
Williams et al. 2018 - Overall cohort	30	77.1	10.0	-+-		77.1	[73.5; 80.7]	2.5%
Random effects model	678				$\diamond$	95.2	[ 91.4; 99.0]	32.6%
Heterogeneity: $I^2 = 94\%$ , $\tau^2 = 44.3115$ , $p < 0.01$								
age = younger								
Cools et al. 2014 – Between 14 and 16	22	105.1	6.5		+	105.1	[102.4; 107.8]	2.5%
Cools et al. 2014 – Under 14 years old	24	104.4	6.5			104.4	[101.8; 107.0]	2.5%
Ellenbecker (b) et al. 2002 – Overall cohort	117	103.7	10.9		+	103.7	[101.7; 105.7]	2.5%
Fernandez et al. 2019 – Under 13 years old – F	32	140.1	18.2		-+-	140.1	[133.8; 146.4]	2.5%
Fernandez et al. 2019 – Under 13 years old – M	32	146.6	18.5		-+-	146.6	[140.2; 153.0]	2.5%
Fernandez et al. 2019 – Under 15 years old – F	28	138.4	17.3		-+-	138.4	[132.0; 144.8]	2.5%
Fernandez et al. 2019 – Under 15 years old – M	36	136.4	14.6		-+-	136.4	[131.6; 141.2]	2.5%
Fernandez et al. 2020 – Before Tennis. Pre-tests F	13	152.5	13.8		-	- 152.5	[145.0; 160.0]	2.4%
Fernandez et al. 2020 – Before Tennis. Pre-tests M	12	149.4	12.3		-+	149.4	[142.4; 156.4]	2.5%
Fernandez–Fernandez et al. 2022 – PreControl	13	146.1	8.8			146.1	[141.3; 150.9]	2.5%
Fernandez–Fernandez et al. 2022 – PreTraining	13	136.8	11.1		-+	136.8	[130.8; 142.8]	2.5%
Gillet et al. 2017 – AHPV–2	20	83.0	10.0	+		83.0	[ 78.6; 87.4]	2.5%
Gillet et al. 2017 – AHPV–3	21	85.0	10.0	+		85.0	[ 80.7; 89.3]	2.5%
Gillet et al. 2017 – AHPV–4	26	84.0	9.0	-+-		84.0	[ 80.5; 87.5]	2.5%
Gillet et al. 2018 – HSP	30	86.0	8.0	+-		86.0	[ 83.1; 88.9]	2.5%
Gillet et al. 2018 – NHSP	61	83.0	9.0	+	_	83.0	[ 80.7; 85.3]	2.5%
Johansson et al. 2022 – All ages F	125	98.5	13.1		+	98.5	[ 96.2; 100.8]	2.5%
Johansson et al. 2022 – All ages M	176	98.4	12.5		+	98.4	[ 96.6; 100.2]	2.5%
McConnell et al. 2009 – Female	10	91.6	10.9		-	91.6	[84.8; 98.4]	2.5%
McConnell et al. 2009 – Male	11	93.7	10.0	+	•• <u>:</u>	93.7	[ 87.8; 99.6]	2.5%
Nutt et al. 2018 – 14–15 years old	56	107.0	9.0			107.0	[104.6; 109.4]	2.5%
Nutt et al. 2018 – Under 14 years old	69	103.0	8.0		-	103.0	[101.1; 104.9]	2.5%
Olivier et al. 2020 – mix	22	107.6	9.4			107.6	[103.7; 111.5]	2.5%
Iooth et al. 2023 – Prepubertal (<14)	24	101.0	4.2		+	101.0	[ 99.3; 102.7]	2.5%
Tooth et al. $2023 - Pubertal (14-18)$	1/	98.3	7.8		+	98.3	[ 94.6; 102.0]	2.5%
Tooth et al. 2023 – Prepubertal (<13)	13	101.1	5.2		+	101.1	[ 98.3; 104.0]	2.5%
lootn et al. $2023 - Pubertal (13-17)$	12	100.1	6.4			100.1	[ 96.5; 103.7]	2.5%
	1035				$\sim$	110.3	[101.6; 118.9]	67.4%
Heterogeneity: $r^{-} = 99\%$ , $\tau^{-} = 522.6741$ , $p = 0$								
Random effects model	1713					105.4	[ 99.0; 111.7]	100.0%
Heterogeneity: $I^2 = 98\%$ , $\tau^2 = 410.2293$ , $p = 0$			ſ					
Test for subgroup differences: $\chi_1^2 = 9.79$ , df = 1 ( $p < 0.01$ )			20	0 40 60 80	100 120 140	160		

Figure 6 Forest plot comparing ER in older vs. younger tennis players. SD, standard deviation; CI, confidence interval; ER, external rotation.

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Study	Total	Mean	SD	тот		Mean	95% CI	Weight
age = older								
Ellenbecker et al. 2020 – With dominant-arm ISP atrophy	92	136.3	10.5	+		136.3	[134.2; 138.5]	3.2%
Ellenbecker et al. 2020 - Without dominant-arm ISP atroph	iy 61	135.9	9.6	+		135.9	[133.5; 138.3]	3.2%
Nutt et al. 2018 – Over 16 year old	59	140.0	35.0			140.0	[131.1; 148.9]	3.1%
Williams et al. 2018 – Overall cohort	30	129.9	15.1	+		129.9	[124.5; 135.3]	3.1%
Noreno-perez et al. 2015 - Overall cohort	47	136.2	15.4	+		136.2	[131.8; 140.6]	3.1%
Cools et al. 2014 – Over 16 years old	13	142.3	11.0	-+-		142.3	[136.3; 148.3]	3.1%
Kovacs et al. 2007 – Pre (test)	8	126.8	11.2	+		126.8	[119.0; 134.5]	3.1%
Schmidt-Wiethoff et al. 2004 - Tennis player	27	132.9	15.0	-+-		132.9	[127.2; 138.6]	3.1%
Ellenbecker (a) et al. 2002 – Pre-season	11	150.0		1		150.0		0.0%
_ópez–Vidriero Tejedor et al. 2023	270	144.5	20.2	+		144.5	[142.1; 146.9]	3.2%
Random effects model	618			♦		136.4	[132.8; 139.9]	28.2%
Heterogeneity: $I^2 = 86\%$ , $\tau^2 = 23.2188$ , $p < 0.01$								
age = vounger								
Johansson et al. 2022 – All ages M	176	155.6	17.4	+		155.6	[153.0: 158.2]	3.2%
Johansson et al. 2022 – All ages F	125	160.0	17.0	+		160.0	[157.0: 163.0]	3.2%
Fernandez et al. 2020 – Before Tennis. Pre-tests M	12	205.4	19.4			205.4	[194.4: 216.4]	3.0%
Fernandez et al. 2020 – Before Tennis, Pre-tests F	13	211.6	18.9			211.6	[201.3: 221.9]	3.1%
Divier et al. 2020 – mix	22	172.3	11.2	+		172.3	[167.7: 177.0]	3.1%
Fernandez et al. 2019 – Under 13 years old – M	32	219.6	26.3	_		219.6	[210.4: 228.7]	3.1%
Fernandez et al. 2019 – Under 15 years old – M	36	198.2	23.4			198.2	[190.5: 205.9]	3.1%
Fernandez et al. 2019 – Under 13 years old – F	32	207.1	25.5		-	207.1	[198.3: 216.0]	3.1%
Fernandez et al. 2019 – Under 15 vears old – F	28	209.4	21.9			209.4	[201.3: 217.5]	3.1%
Gillet et al. 2018 – HSP	30	162.0	12.0	+	_	162.0	[157.7: 166.3]	3.1%
Gillet et al. 2018 – NHSP	61	155.0	15.0	+		155.0	[151.2: 158.8]	3.2%
Nutt et al. 2018 – Under 14 vears old	69	147.0	12.0	+		147.0	[144.2: 149.8]	3.2%
Nutt et al. 2018 – 14–15 vears old	56	146.0	12.0	+		146.0	[142.9: 149.1]	3.2%
Gillet et al. 2017 – AHPV–4	26	161.0	13.0			161.0	[156.0: 166.0]	3.1%
Gillet et al. 2017 – AHPV–3	21	153.0	15.0			153.0	[146.6: 159.4]	3.1%
Gillet et al. 2017 – AHPV–2	20	149.0	16.0	-		149.0	[142.0: 156.0]	3.1%
Cools et al. 2014 – Under 14 years old	24	153.8	9.1	+		153.8	[150.2: 157.4]	3.2%
Cools et al. 2014 – Between 14 and 16	22	148.6	12.4	+		148.6	[143.4: 153.8]	3.1%
VicConnell et al. 2009 – Male	11	135.6	10.1			135.6	[129.6: 141.6]	3.1%
VicConnell et al. 2009 – Female	10	135.0	13.5	<b>.</b>		135.0	[126.6: 143.4]	3.1%
Fllenbecker (b) et al. 2002 – Overall cohort	117	149.1	18.4	+		149.1	[145.8; 152.4]	3.2%
Fernandez-Fernandez et al. 2022 - PreControl	13	204.6	11.1		-+-	204.6	[198.6: 210.6]	3.1%
Fernandez-Fernandez et al. 2022 - PreTraining	13	194.8	20.4		-	194.8	[183 7: 205 9]	3.0%
Random effects model	969	101.0	_0.1	$\diamond$		170.8	[159.5: 182.1]	71.8%
Heterogeneity: $l^2 = 98\%$ , $\tau^2 = 753.0341$ , $p < 0.01$	000			, j			L.colo, iomii]	1 110 /0
Random effects model	1587			$\diamond$		161.0	[151.2: 170.8]	100.0%
Heterogeneity: $l^2 = 99\%$ . $\tau^2 = 788.6899$ . $\rho = 0$						1	[,]	

Figure 7 Forest plot comparing total ROM in older vs. younger tennis players. SD, standard deviation; CI, confidence interval; ROM, range of motion.

#### Dominant vs. nondominant

Comparing dominant vs. nondominant shoulders revealed that dominant shoulders had significantly smaller IR (53.0°, Cl, 49.3-56.6;  $I^2 = 98\%$ , vs. 62.6°, Cl, 58.7-66.5;  $I^2 = 99\%$ ) (Fig. 2). However, there were no significant differences in ER (105.4°, Cl, 99.0-111.7;  $I^2 = 98\%$  vs. 100.8°, Cl, 94.9-106.7  $I^2 = 99\%$ ) (Fig. 3), or total ROM (161.0°, Cl, 151.2-170.8;  $I^2 = 99$  vs. 166.5°, Cl, 156.8-176.3;  $I^2 = 99\%$ ) (Fig. 4).

#### Children vs. adults

Comparing adults vs. children revealed that adults have significantly smaller IR (44.5°, Cl, 41.4-47.5;  $I^2 = 95\%$  vs. 57.1°, Cl, 52.6-61.6;  $I^2 = 98\%$ ) (Fig. 5), ER (95.2°, Cl, 91.4-99.0;  $I^2 = 94\%$  vs. 110.3°, Cl,

101.6-118.9;  $l^2 = 99\%$ ) (Fig. 6), and total ROM (136.4°, CI, 132.8-139.9;  $l^2 = 86\%$  vs. 170.8°, CI, 159.5-182.1;  $l^2 = 98\%$ ) (Fig. 7).

#### Females vs. males

Comparing females vs. males revealed no significant differences in ER (113.4°, Cl, 98.3-128.4;  $I^2 = 98\%$  vs. 104.9°, Cl, 94.6-115.2;  $I^2 = 99\%$ ) (Fig. 8), IR (54.7°, Cl, 48.1-61.4;  $I^2 = 98\%$  vs. 56.3°, Cl, 50.8-61.9;  $I^2 = 98\%$ ) (Fig. 9), or total ROM (184.5°, Cl, 153.8-215.2;  $I^2 = 99\%$  vs. 166.7°, Cl, 151.8-181.6;  $I^2 = 98\%$ ) (Fig. 10).

#### Type of measurement instrumentation

Comparing type of measurement instrumentation revealed that shoulder ROM measured using a goniometer have significantly less

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Study	Total	Mean	SD		ER		Mean	95% CI	Weight
sex = F					÷				
Ellenbecker (a) et al. 2002 - Pre-season	11	101.1	9.1				101.1	[ 95.7: 106.5]	3.4%
Fernandez et al. 2019 – Under 13 years old – F	32	140.1	18.2				140.1	[133.8: 146.4]	3.4%
Fernandez et al. 2019 - Under 15 years old - F	28	138.4	17.3				138.4	[132.0: 144.8]	3.4%
Fernandez et al. 2020 – Before Tennis. Pre-tests F	13	152.5	13.8				152.5	[145.0; 160.0]	3.4%
Johansson et al. 2022 – All ages F	125	98.5	13.1		+		98.5	[ 96.2; 100.8]	3.5%
McConnell et al. 2009 – Female	10	91.6	10.9				91.6	[ 84.8; 98.4]	3.4%
Tooth et al. 2023 – Prepubertal (<13)	13	101.1	5.2		-+-		101.1	[ 98.3; 104.0]	3.5%
Tooth et al. 2023 – Pubertal (13–17)	12	100.1	6.4		-+-		100.1	[ 96.5; 103.7]	3.5%
Tooth et al. 2023 – Postpubertal (>17)	6	98.0	3.6		-+-		98.0	[95.1; 100.9]	3.5%
Random effects model	250				$\sim$	-	113.4	[ 98.3; 128.4]	30.9%
Heterogeneity: $I^2 = 98\%$ , $\tau^2 = 521.0372$ , $p < 0.01$									
sex = M									
Ellenbecker (b) et al. 2002 – Overall cohort	117	103.7	10.9		+		103.7	[101.7; 105.7]	3.5%
Fernandez et al. 2019 – Under 13 years old – M	32	146.6	18.5				146.6	[140.2; 153.0]	3.4%
Fernandez et al. 2019 – Under 15 years old – M	36	136.4	14.6				136.4	[131.6; 141.2]	3.4%
Fernandez et al. 2020 - Before Tennis. Pre-tests M	12	149.4	12.3				149.4	[142.4; 156.4]	3.4%
Fernandez-Fernandez et al. 2022 - PreControl	13	146.1	8.8			-+	146.1	[141.3; 150.9]	3.4%
Fernandez-Fernandez et al. 2022 - PreTraining	13	136.8	11.1				136.8	[130.8; 142.8]	3.4%
Gillet et al. 2017 – AHPV–2	20	83.0	10.0				83.0	[78.6; 87.4]	3.5%
Gillet et al. 2017 – AHPV–3	21	85.0	10.0				85.0	[ 80.7; 89.3]	3.5%
Gillet et al. 2017 – AHPV–4	26	84.0	9.0		-+-		84.0	[ 80.5; 87.5]	3.5%
Gillet et al. 2018 – HSP	30	86.0	8.0		+		86.0	[ 83.1; 88.9]	3.5%
Gillet et al. 2018 – NHSP	61	83.0	9.0		+		83.0	[ 80.7; 85.3]	3.5%
Johansson et al. 2022 – All ages M	176	98.4	12.5		+		98.4	[ 96.6; 100.2]	3.5%
Kovacs et al. 2007 – Pre (test)	8	90.9	6.7		•		90.9	[ 86.2; 95.5]	3.4%
McConnell et al. 2009 – Male	11	93.7	10.0				93.7	[ 87.8; 99.6]	3.4%
Moreno-perez et al. 2015 - Overall cohort	47	90.5	9.0		+		90.5	[ 87.9; 93.1]	3.5%
Palmer et al. 2018 – Overall cohort	42	97.1	13.3		-+-		97.1	[ 93.1; 101.1]	3.5%
Schmidt–Wiethoff et al. 2004 – Tennis player	27	89.1	13.7				89.1	[ 83.9; 94.3]	3.4%
Tooth et al. 2023 – Prepubertal (<14)	24	101.0	4.2		+		101.0	[ 99.3; 102.7]	3.5%
Tooth et al. 2023 – Pubertal (14–18)	17	98.3	7.8		-+-		98.3	[ 94.6; 102.0]	3.5%
Tooth et al. 2023 – Postpubertal (>18)	12	100.4	7.1				100.4	[ 96.4; 104.4]	3.5%
Random effects model	745				$\langle$		104.9	[ 94.6; 115.2]	69.1%
Heterogeneity: $l^2 = 99\%$ , $\tau^2 = 544.2009$ , $p = 0$									
Random effects model	995		_		$\diamond$		107.5	[ 99.1; 116.0]	100.0%
Heterogeneity: $I^2 = 99\%$ , $\tau^2 = 533.7602$ , $p = 0$			I						
Test for subgroup differences: $\chi_1^2 = 0.84$ , df = 1 ( $p = 0.36$ )			20	40 60	80 100 120	0 140 16	0		

Figure 8 Forest plot comparing ER in females vs. males. SD, standard deviation; CI, confidence interval; ER, external rotation.

ER (95.5°, CI, 92.2-98.7;  $I^2 = 96\%$  vs. 119.6°, CI, 108.2-131.1;  $I^2 = 99\%$ ) (Fig. 11), IR (53.3°, CI, 47.1-59.6;  $I^2 = 99\%$  vs. 62.5°, CI, 58.8-66.2;  $I^2 = 89\%$ ) (Fig. 12), and total ROM (146.8°, CI, 141.3-152.2;  $I^2 = 92\%$  vs. 175.4°, CI, 160.3-190.5;  $I^2 = 99\%$ ) (Fig. 13).

#### Discussion

The most important findings of the present meta-analysis on shoulder ROM in tennis players were that, compared to the nondominant shoulders, dominant shoulders had significantly smaller IR (53.0° vs. 62.4°, P < .01). Furthermore, compared to adults, children had significantly greater IR (57.0° vs. 44.4°, P < .01), ER (110.3° vs. 95.3°, P < .01), and total ROM (170.8° vs. 136.4°, P < .01). Moreover, there were several trends between comparative groups, but the differences were not statistically significant; compared to nondominant shoulders, dominant shoulders tended to have greater ER (105.4° vs. 100.8°, P = .310). Finally, compared to males, females tended to have greater ER (113.4° vs. 104.8°, P = .360), but comparable IR (56.4° vs. 54.4°, P = .650). These findings could be relevant in the context of physical preparation

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Study	Total	Mean	SD		IR			Mean	95% CI	Weight
sex = F										
Ellenbecker (a) et al. 2002 – Pre-season	11	48.9	10.2			-		48.9	[42.9; 54.9]	3.3%
Fernandez et al. 2019 – Under 13 years old – F	32	67.1	14.1				-	67.1	[62.2; 72.0]	3.4%
Fernandez et al. 2019 – Under 15 years old – F	28	71.0	10.5			-	+	71.0	[67.1; 74.9]	3.5%
Fernandez et al. 2020 – Before Tennis. Pre-tests F	13	59.1	10.2					59.1	[53.6; 64.6]	3.4%
Johansson et al. 2022 – All ages F	125	61.5	11.6			-+-		61.5	[59.5; 63.5]	3.5%
McConnell et al. 2009 – Female	10	43.2	7.2					43.2	[38.7; 47.7]	3.4%
Tooth et al. 2023 – Prepubertal (<13)	13	45.7	6.1		+			45.7	[42.4; 49.0]	3.5%
Tooth et al. 2023 – Pubertal (13–17)	12	49.6	7.1		-+-	F		49.6	[45.6; 53.6]	3.5%
Tooth et al. 2023 – Postpubertal (>17)	6	46.5	0.7		+			46.5	[45.9; 47.1]	3.6%
Random effects model	250				<	$\sim$		54.7	[48.1; 61.4]	31.0%
Heterogeneity: $l^2 = 98\%$ , $\tau^2 = 99.1811$ , $p < 0.01$										
sex = M										
Ellenbecker (b) et al. 2002 – Overall cohort	117	45.4	13.6		-+			45.4	[42.9; 47.9]	3.5%
Fernandez et al. 2019 – Under 13 years old – M	32	73.0	12.1				1	73.0	[68.8; 77.2]	3.4%
Fernandez et al. 2019 – Under 15 years old – M	36	61.8	13.8					61.8	[57.3; 66.3]	3.4%
Fernandez et al. 2020 - Before Tennis. Pre-tests M	12	56.0	12.9		_			56.0	[48.7; 63.3]	3.2%
Fernandez–Fernandez et al. 2022 – PreControl	13	58.5	7.6					58.5	[54.4; 62.6]	3.4%
Fernandez–Fernandez et al. 2022 – PreTraining	13	58.0	13.0		-	+		58.0	[50.9; 65.1]	3.2%
Gillet et al. 2017 – AHPV–2	20	66.0	9.0			-+-	-	66.0	[62.1; 69.9]	3.5%
Gillet et al. 2017 – AHPV–3	21	69.0	9.0					69.0	[65.2; 72.8]	3.5%
Gillet et al. 2017 – AHPV–4	26	78.0	9.0					78.0	[74.5; 81.5]	3.5%
Gillet et al. 2018 – HSP	30	75.0	10.0					75.0	[71.4; 78.6]	3.5%
Gillet et al. 2018 – NHSP	61	72.0	10.0					72.0	[69.5; 74.5]	3.5%
Johansson et al. 2022 – All ages M	176	57.2	12.2					57.2	[55.4; 59.0]	3.5%
Kovacs et al. 2007 – Pre (test)	8	35.9	6.2					35.9	[31.6; 40.2]	3.4%
McConnell et al. 2009 – Male	11	41.9	7.7					41.9	[37.3; 46.5]	3.4%
Moreno-perez et al. 2015 - Overall cohort	47	45.8	12.1			_		45.8	[42.3; 49.3]	3.5%
Palmer et al. 2018 – Overall cohort	42	51.8	14.4			-		51.8	[47.4; 56.2]	3.4%
Schmidt–Wiethoff et al. 2004 – Tennis player	27	43.8	11.0					43.8	[39.7; 47.9]	3.4%
Tooth et al. 2023 – Prepubertal (<14)	24	47.6	7.6		-+			47.6	[44.6; 50.7]	3.5%
Tooth et al. 2023 – Pubertal (14–18)	17	45.6	4.4		-+-			45.6	[43.5; 47.6]	3.5%
Tooth et al. 2023 – Postpubertal (>18)	12	44.4	3.9		-+			44.4	[42.2; 46.6]	3.5%
Random effects model	745				<	$\diamond$		56.3	[50.8; 61.9]	69.0%
Heterogeneity: $I^2 = 98\%$ , $\tau^2 = 155.4090$ , $p < 0.01$										
Random effects model	995					$\diamond$		55.8	[51.5; 60.1]	100.0%
Heterogeneity: $I^2 = 98\%$ , $\tau^2 = 134.3793$ , $p = 0$				I	I	I	I			
Test for subgroup differences: $\chi_1^2 = 0.13$ , df = 1 ( $p = 0.71$ )				20	40	60	80			

Figure 9 Forest plot comparing IR in females vs. males. SD, standard deviation; CI, confidence interval; IR, internal rotation.

and training of tennis players, to monitor evolution of IR as a result of their sport and/or as they transition from childhood to adulthood.

Several studies have found asymmetric shoulder ROM between dominant and nondominant sides for male and female players, adolescents, and professional players. Furthermore, some studies reported that dominant shoulders have a greater prevalence of early signs of tendinosis and atrophy of the infraspinatus and supraspinatus tendons, ROM deficits, and increased strength.<sup>6,13,16,38</sup> However, it is believed that these are normal sport-adaptations instead of maladaptations. Studies should investigate the source of these adaptations, and whether they are due to soft-tissue or bony changes. A recent study by Paul et al<sup>31</sup> investigated the underlying mechanisms responsible for IR in baseball players, and found that there was increased humeral retroversion and posterior capsule thickness. Unfortunately, Paul et al<sup>31</sup> could not determine a cause-and-effect relationship, and it is unknown whether these changes are due to baseball, or that baseball players have a greater retroversion and capsule thickness.

A clinical study by Moreno-Perez et  $al^{26}$  found that tennis players with a history of shoulder pain have decreased bilateral shoulder IR and total ROM, but did not find side-to-side differences,

Study	Total	Mean	SD			тот		Mean	95% CI	Weight
sex = F						:				
Johansson et al. 2022 – All ages F	125	160.0	17 0			+		160.0	[157.0: 163.0]	51%
Fernandez et al. 2020 – Before Tennis Pre-tests F	13	211.6	18.9					211.6	[201 3: 221 9]	4.9%
Fernandez et al. 2019 – Under 13 years old – F	32	207.1	25.5					207.1	[198.3: 216.0]	5.0%
Fernandez et al. 2019 – Under 15 years old – F	28	209.4	21.9					209.4	[201.3: 217.5]	5.0%
McConnell et al. 2009 – Female	10	135.0	13.5					135.0	[126.6: 143.4]	5.0%
Ellenbecker (a) et al. 2002 - Pre-season	11	150.0						150.0		0.0%
Random effects model	219					$\langle$	>	184.5	[153.8; 215.2]	24.9%
Heterogeneity: $I^2 = 99\%$ , $\tau^2 = 1210.8114$ , $p < 0.01$										
sox – M										
Johansson et al. 2022 – All ages M	176	155.6	174			+		155.6	[153.0: 158.2]	5 1%
Fernandez et al. 2020 – Before Tennis Pre-tests M	12	205.4	19.4					205.4	[194 4: 216 4]	4.9%
Fernandez et al. 2019 – Under 13 years old – M	32	219.6	26.3					219.6	[210.4: 228.7]	5.0%
Fernandez et al. 2019 – Under 15 vears old – M	36	198.2	23.4					198.2	[190.5: 205.9]	5.0%
Gillet et al. 2018 – HSP	30	162.0	12.0			-+-		162.0	[157.7; 166.3]	5.0%
Gillet et al. 2018 – NHSP	61	155.0	15.0			+		155.0	[151.2; 158.8]	5.1%
Gillet et al. 2017 – AHPV–4	26	161.0	13.0			-+-		161.0	[156.0; 166.0]	5.0%
Gillet et al. 2017 – AHPV–3	21	153.0	15.0			-+-		153.0	[146.6; 159.4]	5.0%
Gillet et al. 2017 – AHPV–2	20	149.0	16.0			+-		149.0	[142.0; 156.0]	5.0%
Moreno-perez et al. 2015 - Overall cohort	47	136.2	15.4			+		136.2	[131.8; 140.6]	5.0%
Kovacs et al. 2007 – Pre (test)	8	126.8	11.2		ł	+		126.8	[119.0; 134.5]	5.0%
Schmidt–Wiethoff et al. 2004 – Tennis player	27	132.9	15.0			+		132.9	[127.2; 138.6]	5.0%
Ellenbecker (b) et al. 2002 – Overall cohort	117	149.1	18.4			+		149.1	[145.8; 152.4]	5.1%
Fernandez–Fernandez et al. 2022 – PreControl	13	204.6	11.1					204.6	[198.6; 210.6]	5.0%
Fernandez–Fernandez et al. 2022 – PreTraining	13	194.8	20.4					194.8	[183.7; 205.9]	4.9%
Random effects model	639					$\langle \rangle$	>	166.7	[151.8; 181.6]	75.1%
Heterogeneity: $I^{2} = 98\%$ , $\tau^{2} = 857.2460$ , $p < 0.01$										
Random effects model	858					$\langle$	>	171.1	[157.5; 184.7]	100.0%
Heterogeneity: $l^2 = 99\%$ , $\tau^2 = 948.2729$ , $p < 0.01$						I			-	
Test for subgroup differences: $\chi_1^2 = 1.05$ , df = 1 ( $p = 0.31$ )				50	100	150	200	250		

Figure 10 Forest plot comparing total ROM in females vs. males. SD, standard deviation; CI, confidence interval; ROM, range of motion.

when comparing injured to noninjured shoulders. This was further corroborated in a recent systematic review by Pozzi et al,<sup>32</sup> which aimed to characterize whether preseason screening of shoulder ROM is associated with risks of shoulder and elbow injuries in overhead athletes. Pozzi et al<sup>32</sup> found associations between risk of injury and preseason screening of shoulder ER in baseball pitchers and swimmers, but not in handball, softball, volleyball, or tennis players. Therefore, the reported ROM alterations may represent normal adaptations due to the greater hitting demands, and are therefore not associated with an increased risk of sustaining shoulder injuries.

The results of the present meta-analysis should be interpreted with the following limitations in mind. There was considerable heterogeneity in the age groups of the players, and the reported ROM between the included studies, which could be due to differences in measurement methods, making quantitative comparisons difficult. Furthermore, age could not be considered as a continuous variable as only means were reported in the included studies. Finally, we did not consider shoulder strength, which might be inversely correlated with ROM and could be a confounding variable.

#### Conclusion

IR in shoulders of tennis players is significantly smaller in dominant vs. nondominant sides (53.0° vs. 62.4°, P < .001), and significantly smaller in adults vs. children (44.4° vs. 57.0°, P < .001). These findings could be relevant in the context of physical preparation and training of tennis players, to monitor evolution of IR as a result of their sport and/or as they transition from childhood to adulthood.

#### **Disclaimers:**

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Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not

Study	Total	Mean	SD	E	7	Mean	95% CI	Weight
instrument - Conjemater					:			
$Ellenbecker(\mathbf{a}) \text{ at al. } 2002  Precessor$	44	101.1	0.1			101.1	[ 05 7: 106 F]	0 50/
Ellenbecker (a) et al. 2002 – Fie-season	117	101.1	9.1			101.1	[95.7, 106.5]	2.3%
	117	103.7	10.9			103.7		2.3%
	20	83.0	10.0			83.0	[ /0.0; 0/.4]	2.5%
	21	85.0	10.0			85.0		2.5%
	26	84.0	9.0			84.0	[80.5; 87.5]	2.5%
Gillet et al. 2018 – HSP	30	86.0	8.0			86.0	[83.1; 88.9]	2.5%
Gillet et al. 2018 – NHSP	61	83.0	9.0	+		83.0	[ 80.7; 85.3]	2.5%
Kovacs et al. 2007 – Pre (test)	8	90.9	6.7			90.9	[ 86.2; 95.5]	2.5%
Lopez–Vidriero Tejedor et al. 2023	270	93.8	9.3			93.8	[92.7; 94.9]	2.5%
McConnell et al. 2009 – Female	10	91.6	10.9			91.6	[ 84.8; 98.4]	2.5%
McConnell et al. 2009 – Male	11	93.7	10.0		-	93.7	[87.8; 99.6]	2.5%
Nutt et al. 2018 – 14–15 years old	56	107.0	9.0			107.0	[104.6; 109.4]	2.5%
Nutt et al. 2018 – Over 16 year old	59	101.0	10.0		<b>+</b> .	101.0	[ 98.4; 103.6]	2.5%
Nutt et al. 2018 – Under 14 years old	69	103.0	8.0		+	103.0	[101.1; 104.9]	2.5%
Palmer et al. 2018 – Overall cohort	42	97.1	13.3		-	97.1	[ 93.1; 101.1]	2.5%
Tooth et al. 2023 – Prepubertal (<14)	24	101.0	4.2		+	101.0	[ 99.3; 102.7]	2.5%
Tooth et al. 2023 – Pubertal (14–18)	17	98.3	7.8		+	98.3	[ 94.6; 102.0]	2.5%
Tooth et al. 2023 – Postpubertal (>18)	12	100.4	7.1		+	100.4	[ 96.4; 104.4]	2.5%
Tooth et al. 2023 – Prepubertal (<13)	13	101.1	5.2		+-	101.1	[ 98.3; 104.0]	2.5%
Tooth et al. 2023 – Pubertal (13–17)	12	100.1	6.4		-+-	100.1	[ 96.5; 103.7]	2.5%
Tooth et al. 2023 – Postpubertal (>17)	6	98.0	3.6		+	98.0	[ 95.1; 100.9]	2.5%
Random effects model	895			•	♦ :	95.5	[ 92.2; 98.7]	52.6%
Heterogeneity: $l^2 = 96\%$ , $\tau^2 = 54.2326$ , $p < 0.01$								
instrument = Inclinometer								
Cools et al. 2014 – Between 14 and 16	22	105.1	6.5		+	105.1	[102.4; 107.8]	2.5%
Cools et al. 2014 – Over 16 years old	13	101.7	11.9			101.7	[ 95.2; 108.2]	2.5%
Cools et al. 2014 – Under 14 years old	24	104.4	6.5		+	104.4	[101.8; 107.0]	2.5%
Ellenbecker et al. 2020 – With dominant-arm ISP atrophy	92	99.7	7.7		+	99.7	[ 98.1; 101.3]	2.5%
Ellenbecker et al. 2020 - Without dominant-arm ISP atrophy	61	97.7	9.0		+	97.7	[ 95.4; 99.9]	2.5%
Fernandez et al. 2019 – Under 13 years old – F	32	140.1	18.2		-+-	140.1	[133.8; 146.4]	2.5%
Fernandez et al. 2019 – Under 13 years old – M	32	146.6	18.5		-+-	146.6	[140.2; 153.0]	2.5%
Fernandez et al. 2019 – Under 15 years old – F	28	138.4	17.3			138.4	[132.0; 144.8]	2.5%
Fernandez et al. 2019 – Under 15 years old – M	36	136.4	14.6		-	136.4	[131.6; 141.2]	2.5%
Fernandez et al. 2020 – Before Tennis. Pre-tests F	13	152.5	13.8		-+-	152.5	[145.0; 160.0]	2.4%
Fernandez et al. 2020 – Before Tennis. Pre-tests M	12	149.4	12.3			149.4	[142.4; 156.4]	2.5%
Fernandez–Fernandez et al. 2022 – PreControl	13	146.1	8.8			146.1	[141.3; 150.9]	2.5%
Fernandez–Fernandez et al. 2022 – PreTraining	13	136.8	11.1			136.8	[130.8; 142.8]	2.5%
Johansson et al. 2022 – All ages F	125	98.5	13.1		+	98.5	[ 96.2; 100.8]	2.5%
Johansson et al. 2022 – All ages M	176	98.4	12.5		+	98.4	[ 96.6; 100.2]	2.5%
Olivier et al. 2020 – mix	22	107.6	9.4			107.6	[103.7: 111.5]	2.5%
Williams et al. 2018 - Overall cohort	30	77.1	10.0	-+-		77.1	[73.5: 80.7]	2.5%
Random effects model	744				$\diamond$	119.6	[108.2: 131.1]	42.4%
Heterogeneity: $l^2 = 99\%$ , $\tau^2 = 569.6739$ , $p = 0$							[	
instrument = Others								
Moreno-perez et al. 2015 - Overall cohort	47	90.5	9.0	+		90.5	[87.9:93.1]	2.5%
Schmidt–Wiethoff et al. 2004 – Tennis plaver	27	89.1	13.7			89.1	[83.9: 94.3]	2.5%
Random effects model	74	20.1		0		90.2	[ 87.9: 92.5]	5.0%
Heterogeneity: $l^2 = 0\%$ , $\tau^2 = 0$ , $p = 0.63$				·		- V Im	Letter, onto]	010/0
Random effects model	1713				$\diamond$	105.4	[ 99.0: 111.7]	100.0%
Heterogeneity: $I^2 = 98\%$ , $\tau^2 = 410.2293$ . $p = 0$								
Test for subgroup differences: $\chi_2^2 = 28.66$ , df = 2 ( $p < 0.01$ )			2	0 40 60 80	100 120 140 16	60		

Figure 11 Forest plot comparing ER considering type of measurement. SD, standard deviation; CI, confidence interval; ER, external rotation.

Study	Total	Mean	SD	IR	Mean	95% CI	Weight
instrument = Goniometer							
Ellenbecker (a) et al. 2002 - Pre-season	11	48.9	10.2	+	48.9	[42.9; 54.9]	3.3%
Ellenbecker (b) et al. 2002 - Overall cohort	117	45.4	13.6		45.4	[42.9; 47.9]	3.5%
Gillet et al. 2017 – AHPV–2	20	66.0	9.0		66.0	[62.1: 69.9]	3.5%
Gillet et al. 2017 – AHPV–3	21	69.0	9.0		69.0	[65.2: 72.8]	3.5%
Gillet et al. 2017 – AHPV-4	26	78.0	9.0		78.0	[74.5: 81.5]	3.5%
Gillet et al. 2018 – HSP	30	75.0	10.0		75.0	[71.4: 78.6]	3.5%
Gillet et al. 2018 – NHSP	61	72.0	10.0		72.0	[69.5: 74.5]	3.5%
Kovacs et al. 2007 - Pre (test)	8	35.9	6.2		35.9	[31.6; 40.2]	3.4%
McConnell et al. 2009 - Female	10	43.2	7.2		43.2	[38.7: 47.7]	3.4%
McConnell et al. 2009 – Male	11	41.9	7.7		41.9	[37.3: 46.5]	3.4%
Palmer et al. 2018 – Overall cohort	42	51.8	14.4		51.8	[47.4: 56.2]	3.4%
Tooth et al. 2023 – Prepubertal (<14)	24	47.6	7.6	-+-	47.6	[44.6: 50.7]	3.5%
Tooth et al. 2023 – Pubertal (14–18)	17	45.6	4.4	+	45.6	[43.5; 47.6]	3.5%
Tooth et al. 2023 – Postpubertal (>18)	12	44.4	3.9	-	44.4	[42.2: 46.6]	3.5%
Tooth et al. 2023 – Prepubertal (<13)	13	45.7	6.1	+	45.7	[42.4; 49.0]	3.5%
Tooth et al. 2023 – Pubertal (13–17)	12	49.6	7.1		49.6	[45.6: 53.6]	3.5%
Tooth et al. 2023 – Postpubertal (>17)	6	46.5	0.7	+	46.5	[45.9: 47.1]	3.6%
Random effects model	441			$\sim$	53.3	[47.1: 59.6]	59.0%
Heterogeneity: $I^2 = 99\%$ , $\tau^2 = 168.6058$ , $p < 0.01$						. ,	
instrument = Inclinometer Fernandez et al. 2019 – Under 13 years old – F Fernandez et al. 2019 – Under 13 years old – M Fernandez et al. 2019 – Under 15 years old – F	32 32 28	67.1 73.0 71.0	14.1 12.1			[62.2; 72.0] [68.8; 77.2] [67.1: 74.9]	3.4% 3.4% 3.5%
Fornandoz et al. 2019 - Under 15 years old - 1	20	61.0	12.2	_	- 61.8	[07.1, 74.3]	3.1%
Fernandez et al. 2019 – Onder 15 years old – M Fernandez et al. 2020 – Before Tennis, Pre-tests F	13	59.1	10.2		- 59.1	[57.5, 00.5]	3.4%
Fernandez et al. 2020 – Before Tennis, Pre-tests M	12	56.0	12.0		- 56.0	[33.0, 04.0]	3.2%
Fernandez Er al. 2020 - Delore Termis. The-tests in	12	58.5	7.6		L 585	[40.7, 00.0]	3.1%
Fernandez-Fernandez et al. 2022 - PreTraining	13	58.0	13.0		- 58.0	[50.9.65.1]	3.2%
Johansson et al. 2022 – All ages F	125	61 5	11.6		61.5	[50.5, 63.5]	3.5%
Johansson et al. 2022 – All ages M	176	57.2	12.2		57.2	[55.4:59.0]	3.5%
Bandom effects model	480	07.2	12.2	<	⇒ 62.5	[58 8: 66 2]	34.1%
Heterogeneity: $l^2 = 89\%$ , $\tau^2 = 30.6183$ , $p < 0.01$	400				• 02.0	[00.0, 00.2]	04.170
instrument = Others							
Moreno-perez et al. 2015 - Overall cohort	47	45.8	12.1		45.8	[42.3; 49.3]	3.5%
Schmidt–Wiethoff et al. 2004 – Tennis player	27	43.8	11.0		43.8	[39.7; 47.9]	3.4%
Random effects model	74			$\diamond$	45.0	[42.3; 47.6]	6.9%
Heterogeneity: $l^2 = 0\%$ , $\tau^2 = 0$ , $p = 0.47$							
Random effects model	995			$\diamond$	55.8	[51.5; 60.1]	100.0%
Heterogeneity: $I^2 = 98\%$ , $\tau^2 = 134.3793$ , $p = 0$	-					- / -	
Test for subgroup differences: $\chi^2_2 = 56.64$ , df = 2 ( $p < 0.01$	)			20 40 60	0 80		

Figure 12 Forest plot comparing IR considering type of measurement. SD, standard deviation; CI, confidence interval; IR, internal rotation.

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Study	Total	Mean	SD	тот		Mean	95% CI	Weight
instrument = Goniometer					÷			
Gillet et al. 2018 – HSP	30	162.0	12.0		÷	162.0	[157.7: 166.3]	3.1%
Gillet et al. 2018 – NHSP	61	155.0	15.0		+	155.0	[151.2; 158.8]	3.2%
Nutt et al. 2018 – Under 14 years old	69	147.0	12.0	-		147.0	[144.2; 149.8]	3.2%
Nutt et al. 2018 - 14-15 years old	56	146.0	12.0	+		146.0	[142.9; 149.1]	3.2%
Nutt et al. 2018 – Over 16 year old	59	140.0	35.0	· •		140.0	[131.1; 148.9]	3.1%
Gillet et al. 2017 – AHPV-4	26	161.0	13.0		+	161.0	[156.0; 166.0]	3.1%
Gillet et al. 2017 – AHPV–3	21	153.0	15.0		+	153.0	[146.6; 159.4]	3.1%
Gillet et al. 2017 – AHPV–2	20	149.0	16.0	-		149.0	[142.0; 156.0]	3.1%
McConnell et al. 2009 – Male	11	135.6	10.1	-+-		135.6	[129.6; 141.6]	3.1%
McConnell et al. 2009 – Female	10	135.0	13.5	-+		135.0	[126.6; 143.4]	3.1%
Kovacs et al. 2007 – Pre (test)	8	126.8	11.2	-+-		126.8	[119.0; 134.5]	3.1%
Ellenbecker (a) et al. 2002 – Pre-season	11	150.0				150.0		0.0%
Ellenbecker (b) et al. 2002 – Overall cohort	117	149.1	18.4			149.1	[145.8; 152.4]	3.2%
López-Vidriero Tejedor et al. 2023	270	144.5	20.2	+		144.5	[142.1; 146.9]	3.2%
Random effects model	769			\$	•	146.8	[141.3; 152.2]	40.7%
Heterogeneity: $I^{2} = 92\%$ , $\tau^{2} = 92.3816$ , $p < 0.01$								
instrument = Inclinometer								
Johansson et al. 2022 – All ages M	176	155.6	17.4		+	155.6	[153.0; 158.2]	3.2%
Johansson et al. 2022 – All ages F	125	160.0	17.0	_	+	160.0	[157.0; 163.0]	3.2%
Ellenbecker et al. 2020 – With dominant–arm ISP atrophy	92	136.3	10.5	+		136.3	[134.2; 138.5]	3.2%
Ellenbecker et al. 2020 – Without dominant–arm ISP atrophy	61	135.9	9.6	+	_	135.9	[133.5; 138.3]	3.2%
Fernandez et al. 2020 – Before Tennis. Pre-tests M	12	205.4	19.4			205.4	[194.4; 216.4]	3.0%
Fernandez et al. 2020 – Before Tennis. Pre-tests F	13	211.6	18.9		-	211.6	[201.3; 221.9]	3.1%
Olivier et al. 2020 – mix	22	1/2.3	11.2		+	1/2.3	[167.7; 177.0]	3.1%
Fernandez et al. 2019 – Under 13 years old – M	32	219.6	26.3			219.6	[210.4; 228.7]	3.1%
Fernandez et al. 2019 – Under 15 years old – M	30	198.2	23.4			198.2	[190.5; 205.9]	3.1%
Fernandez et al. 2019 – Under 13 years old – F	32	207.1	20.0			207.1	[198.3; 210.0]	3.1% 2.1%
Williams at al. 2019 – Onder 15 years old – F	20	209.4	21.9			209.4	[201.3, 217.3]	0.1% 0.1%
Coole et al. 2014 Under 14 years old	24	152.9	0.1			152.9	[124.3, 133.3]	2.1/0
Cools et al. $2014 - Between 14 and 16$	24	148.6	9.1 12.4			148.6	[130.2, 157.4]	3.2%
Cools et al. $2014 - Over 16 vears old$	13	142.3	11.0			142.3	[136.3: 148.3]	3.1%
Fernandez-Fernandez et al. 2022 – PreControl	13	204.6	11.0		+	204.6	[198.6: 210.6]	3.1%
Fernandez-Fernandez et al. 2022 - Pretraining	13	194.8	20.4		-	194.8	[183 7: 205 9]	3.0%
Random effects model	744	101.0	20.1		$\diamond$	175.4	[160.3: 190.5]	53.0%
Heterogeneity: $I^2 = 99\%$ , $\tau^2 = 995.7606$ , $p = 0$							[]	
instrument = Others								
Moreno-perez et al. 2015 - Overall cohort	47	136.2	15.4	-+-		136.2	[131.8; 140.6]	3.1%
Schmidt-Wiethoff et al. 2004 – Tennis player	27	132.9	15.0	-+-		132.9	[127.2; 138.6]	3.1%
Random effects model	74			\$		135.0	[131.5; 138.4]	6.3%
Heterogeneity: $l^2 = 0\%$ , $\tau^2 = 0$ , $p = 0.37$								
Random effects model	1587				$\diamond$	161.0	[151.2; 170.8]	100.0%
Heterogeneity: $I^2 = 99\%$ , $\tau^2 = 788.6899$ , $p = 0$							-	
Test for subgroup differences: $\chi^2_2$ = 35.09, df = 2 ( $p < 0.01$ )				50 100 15	50 200 25	50		

Figure 13 Forest plot comparing total ROM considering type of measurement. SD, standard deviation; Cl, confidence interval; ROM, range of motion.

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#### **Supplementary Data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jseint.2024.01.017.

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