JSES International 8 (2024) 551–569

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

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

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ARTICLE INFO

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° vs. 62.6°; $P < .001$). Comparing adults vs. children revealed that adults have significantly smaller IR (44.5° vs. 57.1°; $P < .001$) and ER (95.3° vs. 110.3°; $P < .001$). Comparing females vs. males revealed no significant differences in ER (113.4° vs. 104.9°; $P = .360$) or IR (54.3° vs. 56.4°; $P = .710$).
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.

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.[2,10,11] Tennis also requires large shoulder range of motion (ROM), coupled with great forces to achieve high velocities.[1,3,7,33,37]

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).[5,11-13,27,29,33] 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.[20,21] Furthermore, tennis players with a history of shoulder pain have decreased bilateral IR and total ROM,[26] but there might not be an association between shoulder ROM and risk of injury.[32] 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 meta-analysis 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.
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https://doi.org/10.1016/j.jseint.2024.01.017
2666-6383/

Table I
Included studies, demographics, and instrumentation.

Author	Year	Country	Cohort					Hours played per week?		Level of experience		Instruments
Journals			Overall	Sex		Age	BMI	Tennis	Conditioning	Practice	Level of experience	ROM type of measurement
				♂	♀	Mean ± SD		(h/week)	(h/week)	(y)		
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 Tennis Number 1-3	Goniometer
			12	12		>18						
			13		13	<13						
			12		12	13-17						
			6		6	>17						
Fernandez-Fernandez	2022	Spain	13	13		14.6 ± 0.3		21.4 ± 0.8	5.8 ± 0.4	6.1 ± 2.2		Inclinometer (ISOMED inclinometer)
J Strength Cond Res			13	13		14.7 ± 0.3		20.4 ± 1.2	5.7 ± 0.5			
Johansson	2022	Sweden	176	176		14.4 ± 2.0	20.2	>8			National (50) and regional (251)	Smartphone inclinometer app (GetMyROM)
Frontiers in Sports and Active Living			125		125	14.6 ± 2.0	20.2					
Ellenbecker	2020	USA	92	92		25.6 ± 3.6					Professionals (ATP ranked)	Digital inclinometer (Pro 3600 SPI-Tronic)
OJSM			61	61		26.9 ± 3.9						
Fernandez-Fernandez	2020	Spain	12	12		14.9 ± 0.9	19.9	8-10	2	7.5 ± 1.2		Inclinometer (ISOMED inclinometer)
lnt. J. Environ. Res. Public Health			13		13	14.5 ± 0.9	19.9					
Olivier	2020	Brazil	22			12.5 ± 0.9	18.9			3.6 ± 2.5		Digital inclinometer (Fab. Ent. and Lafayette Instr.)
The lnt J of Sports Phys Ther												
Fernandez-Fernandez	2019	Spain	32	32		12.6 ± 0.2	18.1	14 ± 3.1		6.6 ± 3.2		Inclinometer (ISOMED inclinometer)
PLOS ONE			36	36		14.6 ± 0.3	20.9					
			32		32	12.6 ± 0.3	19.2					
			28		28	14.6 ± 0.3	20.5					
Gillet	2018	France	30	30		11.5 ± 2.0	17.2	8.6 ± 2.8	2.5 ± 1.6	6.1 ± 2.5		Goniometer
Physical Therapy in Sport			61	61		11.2 ± 1.8	17.1	8.3 ± 2.5	2.4 ± 1.7	6.2 ± 2.2		
Nutt	2018	United Kingdom	69	122	62	11-14						Goniometer
The lnt J of Sports Phys Ther			56			14-16						
			59			16-24						
Palmer	2018	USA	42	42		23.9 ± 5.8				(4.5 - 6)	NTRP	Goniometer
SPORTS HEALTH												
Williams	2018		30	18	12	20.0				14 (7-24)		Digital inclinometer (Wixey WR360)
Physical Therapy in Sport												
Gillet	2017	France	26	26		8.7 ± 0.7	15.9	6.5 ± 2.3	1.1 ± 1.2	4.1 ± 1.1		Goniometer
Journal of Athletic Training			21	21		10.3 ± 0.6	16.5	8.1 ± 2.4	1.5 ± 1.1			
			20	20		12.8 ± 1.4	17.1	9.2 ± 2.1	3.4 ± 1.8			
Moreno-perez	2015	Spain	47	47		23.2 ± 4.9	23.0			5.9 ± 3.9	[yrs of practice 16.2 ± 5.6]	Photograph (Canon IXUS75 digital camera)
Manual Therapy												
Cools	2014	Sweden	24	31	28		18.9	12.3				Digital inclinometer (model ACU360)
Journal of Athletic Training	22				20.0	15.3						
			13				24.4	15.6				
McConnell	2009	Australia	11	11		16.8 ± 1.3					Elite junior (NSWIS)	Goniometer
Clin J Sport Med			10		10	14.9 ± 0.8						
Kovacs	2007	USA	8	8							Nationally ranked NCAA	Goniometer
Br J Sports Med												
Schmidt-Wiethoff	2004	Germany	27	27		26.5 [19-33]				(10-22)	ATP ranked (1 to 93)	3D real-time motion analysis system (CMS 70P)
lnt J Sports Med												

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 ± 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 ± 0.4	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 ± 4.0				Professionals	Inclinometer
Thomas Journal of Athletic Training	2009	USA	10		10	15.5 ± 1.1				High school (competitive)	Digital Inclinometer
Çolak BJSM	2004		21	21		27.6 ± 0.7	4 h/day (since 12-15 years)				Biodex System 3 (Biodex Medical Systems)

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.

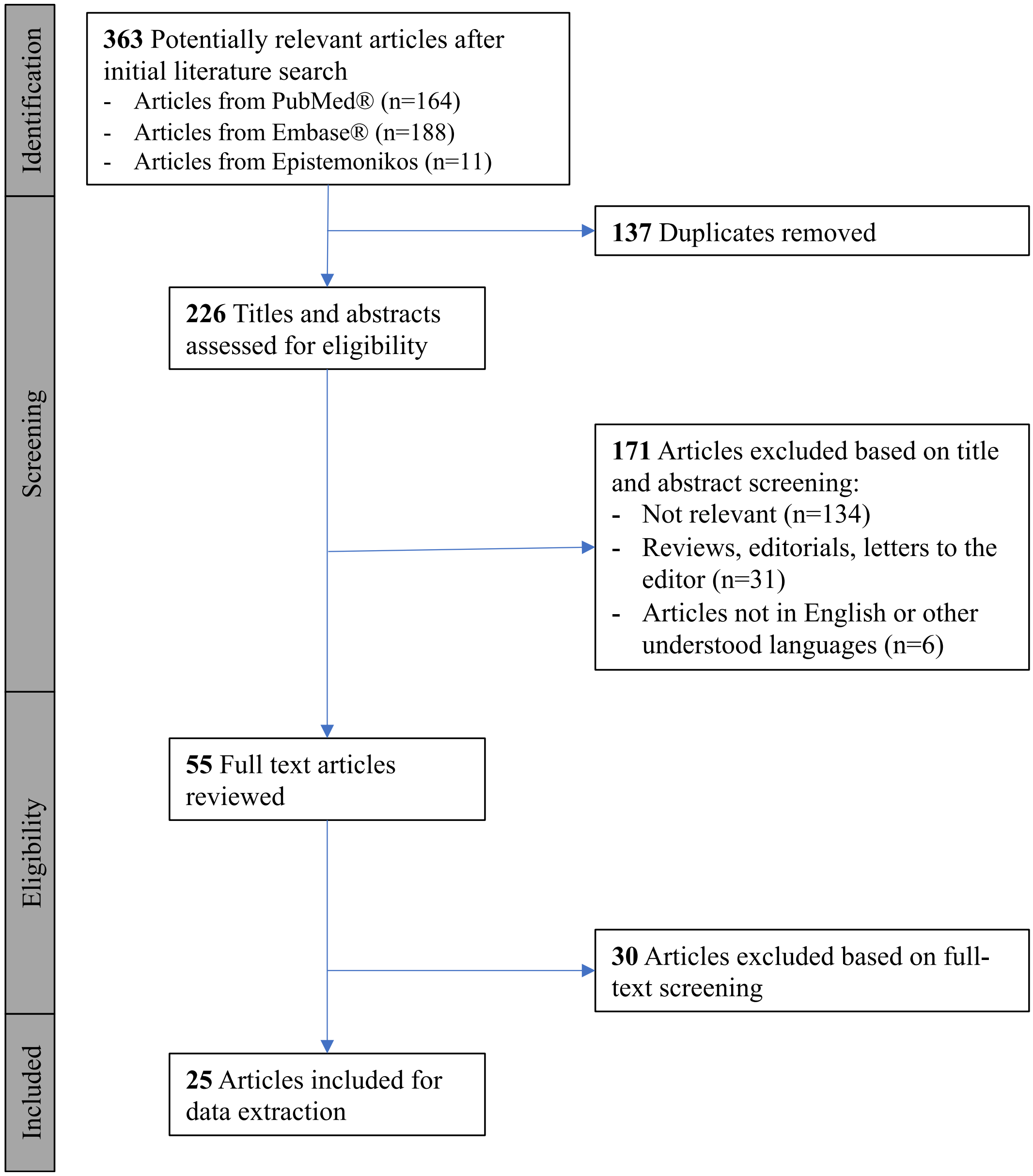


Figure 1 Flowchart.

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,[14] 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).[23]

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.

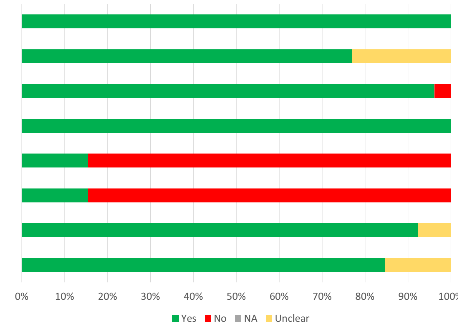
Table II
Included studies, demographics, and range of motion.

Author	Year	Country	Cohort				Dominant			Nondominant		
Journals			Overall	Sex		Age	IR	ER	Total	IR	ER	Total
				♂	♀	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Lopez-Vidriero Tejedor	2023	Spain	270	78	57	22.1 ± 4.9	51 ± 18	94 ± 9	145 ± 20	68 ± 17	93 ± 8	161 ± 19
KSSTA												
Tooth	2023	Belgium	24	24		<14	48 ± 8	101 ± 4		48 ± 6	97 ± 5	
J Sports Med Phys Fitness			17	17		14-18	46 ± 4	98 ± 8		50 ± 6	95 ± 6	
			12	12		>18	44 ± 4	100 ± 7		46 ± 3	96 ± 9	
			13		13	<13	46 ± 6	101 ± 5		46 ± 6	98 ± 5	
			12		12	13-17	50 ± 7	100 ± 6		51 ± 9	100 ± 7	
			6		6	>17	47 ± 1	98 ± 4		46 ± 0	97 ± 8	
Fernandez-Fernandez	2020	Spain	13	13		14.6 ± 0.3	59 ± 8	146 ± 9	205 ± 11	70 ± 9	127 ± 10	198 ± 8
J Strength CondRes			13	13		14.7 ± 0.3	58 ± 13	137 ± 11	195 ± 20	77 ± 12	137 ± 16	214 ± 21
Johansson	2022	Sweden	176	176		14.4 ± 2.0	57 ± 12	98 ± 13	156 ± 17	65 ± 12	91 ± 13	157 ± 18
Frontiers in Sports and Active Living			125		125	14.6 ± 2.0	62 ± 12	99 ± 13	160 ± 17	72 ± 13	94 ± 13	165 ± 17
Ellenbecker	2020	USA	92	92		25.6 ± 3.6	37 ± 8	100 ± 8	136 ± 10	46 ± 7	94 ± 13	142 ± 8
OJSM			61	61		26.9 ± 3.9	38 ± 8	98 ± 9	136 ± 10	46 ± 6	94 ± 9	140 ± 9
Fernandez-Fernandez	2020	Spain	12	12		14.9 ± 0.9	56 ± 13	149 ± 12	205 ± 19	70 ± 14	136 ± 10	205 ± 18
Int. J. Environ. Res. Public Health			13		13	14.5 ± 0.9	59 ± 10	153 ± 14	212 ± 19	68 ± 14	137 ± 14	206 ± 20
Olivier	2020	Brazil	22			12.5 ± 0.9	65 ± 8	108 ± 9	172 ± 11	71 ± 9	98 ± 10	169 ± 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			36	36		14.6 ± 0.3	62 ± 14	136 ± 15	198 ± 23	78 ± 11	134 ± 15	212 ± 20
			32		32	12.6 ± 0.3	67 ± 14	140 ± 18	207 ± 26	80 ± 18	140 ± 12	220 ± 24
			28		28	14.6 ± 0.3	71 ± 11	138 ± 17	209 ± 22	81 ± 14	140 ± 15	221 ± 24
Gillet	2018	France	30	30		11.5 ± 2.0	75 ± 10	86 ± 8	162 ± 12	80 ± 8	85 ± 8	165 ± 13
Physical Therapy in Sport			61	61		11.2 ± 1.8	72 ± 10	83 ± 9	155 ± 15	77 ± 10	82 ± 10	159 ± 16
Nutt	2018	United Kingdom	69	122	62	11-14	44 ± 11	103 ± 8	147 ± 12	47 ± 11	100 ± 7	147 ± 12
The Int J of Sports Phys Ther			56			14-16	38 ± 10	107 ± 9	146 ± 12	45 ± 10	102 ± 8	148 ± 12
			59			16-24	43 ± 13	101 ± 10	140 ± 35	52 ± 14	97 ± 10	138 ± 34
Palmer	2018	USA	42	42		23.9 ± 5.8	52 ± 14	97 ± 13		69 ± 10	87 ± 11	
Sports Health												
Williams	2018		30	18	12	20.0	53 ± 9	77 ± 10	130 ± 15	60 ± 10	76 ± 11	136 ± 14
Physical Therapy in Sport												
Gillet	2017	France	26	26		8.7 ± 0.7	78 ± 9	84 ± 9	161 ± 13	81 ± 9	83 ± 6	163 ± 13
Journal of Athletic Training			21	21		10.3 ± 0.6	69 ± 9	85 ± 10	153 ± 15	76 ± 9	83 ± 11	158 ± 15
			20	20		12.8 ± 1.4	66 ± 9	83 ± 10	149 ± 16	74 ± 11	79 ± 12	154 ± 17
Moreno-perez	2015	Spain	47	47		23.2 ± 4.9	46 ± 12	91 ± 9	136 ± 15	59 ± 12	84 ± 8	142 ± 15
Manual Therapy												
Cools	2014	Sweden	24	31	28		49 ± 8	104 ± 7	154 ± 9	59 ± 7	100 ± 5	160 ± 8
Journal of Athletic Training			22				43 ± 11	105 ± 7	149 ± 12	58 ± 8	98 ± 8	157 ± 11
			13				41 ± 7	102 ± 12	142 ± 11	56 ± 9	100 ± 11	155 ± 13
McConnell	2009	Australia	11	11		16.8 ± 1.3	42 ± 8	94 ± 10	136 ± 10	55 ± 7	91 ± 10	146 ± 15
Clin J Sport Med			10		10	14.9 ± 0.8	43 ± 7	92 ± 11	135 ± 14	58 ± 9	85 ± 7	143 ± 9
Kovacs	2007	USA		88			36 ± 6	91 ± 7	127 ± 11	47 ± 6	87 ± 6	134 ± 9
Br J Sports Med												
Schmidt-Wiethoff	2004	Germany	27	27		26.5 [19-33]	44 ± 11	89 ± 14	133 ± 15	61 ± 7	81 ± 10	142 ± 12
Int J Sports Med												
Ellenbecker (a)	2002	USA	11		11	19.2 ± 1.8	49 ± 10	101 ± 9	150	61 ± 8	95 ± 6	156
Journal of Strength and Conditioning Research												
Ellenbecker (b)	2002	USA	117	117		16.4 ± 1.6	45 ± 14	104 ± 11	149 ± 18	56 ± 12	102 ± 11	158 ± 16
Medicine & Science in Sports & Exercise												

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

Table III
JBI checklist for analytical cross-sectional studies.

Case series		Çolak et al. (2004)	Cools et al. (2014)	Ellenbecker et al. (2002a)	Ellenbecker et al. (2002b)	Ellenbecker et al. (2020)	Fernandez-Ferna et al.(2019)	Fernandez-Ferna et al.(2020)	Fernandez-Ferna et al.(2023)	Gillet et al. (2017)	Gillet et al. (2018)	Johansson et al. (2022)	Kovacs et al. (2007)	Le Solliec (2023)	Martin et al. (2016)	McConnell et al. (2009)	Moore-Reed et al. (2016)	Moreno-Pérez et al. (2015)	Nutt et al. (2018)	Olivier et al. (2020)	Palmer et al. (2018)	Schmidt-Wiethoff et al. (2003)	Schmidt-Wiethoff et al. (2004)	Lopéz-Vidriero Tejedor et al. (2023	Thomas et al. (2009)	Tooth et al. (2023)	Williams et al. (2018)
1	Were the criteria for inclusion in the sample clearly defined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2	Were the study subjects and the setting described in detail?	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	U	Y	Y	Y	Y	Y	U	U	Y	Y	Y	U
3	Was the exposure measured in a valid and reliable way?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
4	Were objective, standard criteria used for measurement of the condition ?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
5	Were confounding factors identified?	N	N	N	Y	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N
6	Were strategies to deal with confounding factors stated?	N	N	N	Y	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N
7	Were the outcomes measured in a valid and reliable way?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	U	Y	Y	Y	Y	Y	Y
8	Was appropriate statistical analysis used?	U	Y	Y	U	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y



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).[24] 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 I^2 statistic and its connected χ^2 test, to provide a measure of the degree of inconsistency across studies.[15] 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% CIs 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).[4-13,16-19,21,22,25,27-30,33-36] 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[7,8,21,22,33,36] studies did not clearly describe the study subjects and/or setting.

Study	Total	Mean	SD	Mean	95% CI	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	8.2	49.4	[46.1; 52.7]	1.3%
Ellenbecker (a) et al. 2002 – Pre–season	11	48.9	10.2	48.9	[42.9; 54.9]	1.2%
Ellenbecker (b) et al. 2002 – Overall cohort	117	45.4	13.6	45.4	[42.9; 47.9]	1.3%
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	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	36	61.8	13.8	61.8	[57.3; 66.3]	1.3%
Fernandez et al. 2020 – Before Tennis. Pre–tests F	13	59.1	10.2	59.1	[53.6; 64.6]	1.2%
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 – HSP	30	75.0	10.0	75.0	[71.4; 78.6]	1.3%
Gillet et al. 2018 – NHSP	61	72.0	10.0	72.0	[69.5; 74.5]	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	7.7	41.9	[37.3; 46.5]	1.3%
Moreno–perez et al. 2015 – Overall cohort	47	45.8	12.1	45.8	[42.3; 49.3]	1.3%
Nutt et al. 2018 – 14–15 years old	56	38.0	10.0	38.0	[35.4; 40.6]	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)	17	45.6	4.4	45.6	[43.5; 47.6]	1.3%
Tooth et al. 2023 – Postpubertal (>18)	12	44.4	3.9	44.4	[42.2; 46.6]	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: $I^2 = 98\%$, $\tau^2 = 134.8615$, $p = 0$						
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 (b) et al. 2002 – Overall cohort	117	56.3	11.5	56.3	[54.2; 58.4]	1.3%
Ellenbecker et al. 2020 – With dominant–arm ISP atrophy	92	46.3	6.9	46.3	[44.9; 47.7]	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 et al. 2020 – Before Tennis. Pre–tests M	12	69.5	14.2	69.5	[61.5; 77.5]	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	30	80.0	8.0	80.0	[77.1; 82.9]	1.3%
Gillet et al. 2018 – NHSP	61	77.0	10.0	77.0	[74.5; 79.5]	1.3%
Johansson et al. 2022 – All ages F	125	71.5	13.4	71.5	[69.2; 73.8]	1.3%
Johansson et al. 2022 – All ages M	176	65.4	11.6	65.4	[63.7; 67.1]	1.3%
Kovacs et al. 2007 – Pre (test)	8	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. 2018 – Over 16 year old	59	52.0	14.0	52.0	[48.4; 55.6]	1.3%
Nutt et al. 2018 – Under 14 years old	69	47.0	11.0	47.0	[44.4; 49.6]	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	48.4	[45.9; 50.9]	1.3%
Tooth et al. 2023 – Pubertal (14–18)	17	49.8	5.8	49.8	[47.0; 52.5]	1.3%
Tooth et al. 2023 – Postpubertal (>18)	12	46.3	3.5	46.3	[44.3; 48.2]	1.3%
Tooth et al. 2023 – Prepubertal (<13)	13	45.5	6.3	45.5	[42.1; 48.9]	1.3%
Tooth et al. 2023 – Pubertal (13–17)	12	51.0	9.0	51.0	[45.9; 56.1]	1.2%
Tooth et al. 2023 – Postpubertal (>17)	6	46.0	0.0	46.0		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			62.6	[58.7; 66.5]	49.3%
Heterogeneity: $I^2 = 99\%$, $\tau^2 = 147.3233$, $p = 0$						
Random effects model	**3426**			**57.7**	**[54.9; 60.6]**	**100.0%**
Heterogeneity: $I^2 = 99\%$, $\tau^2 = 162.2584$, $p = 0$						
Test for subgroup differences: $\chi^2_1 = 12.60$, df = 1 ($p < 0.01$)						

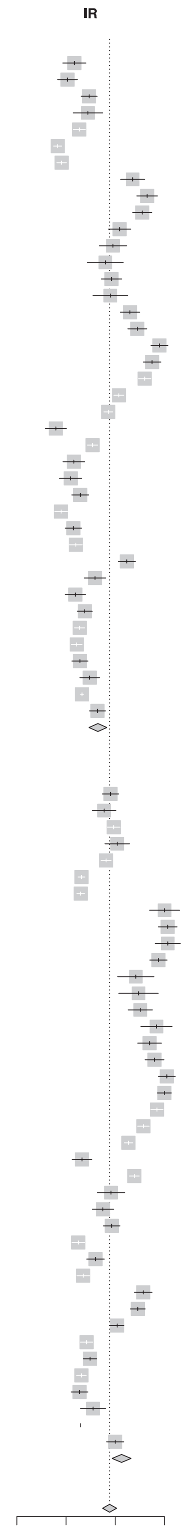


Figure 2 Forest plot comparing IR in dominant vs. nondominant side. The squares represent the mean values of the individual studies; the first and second diamonds represent the weighted means of the respective groups, and the third diamond represents the overall weighted mean, also shown using the *dotted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

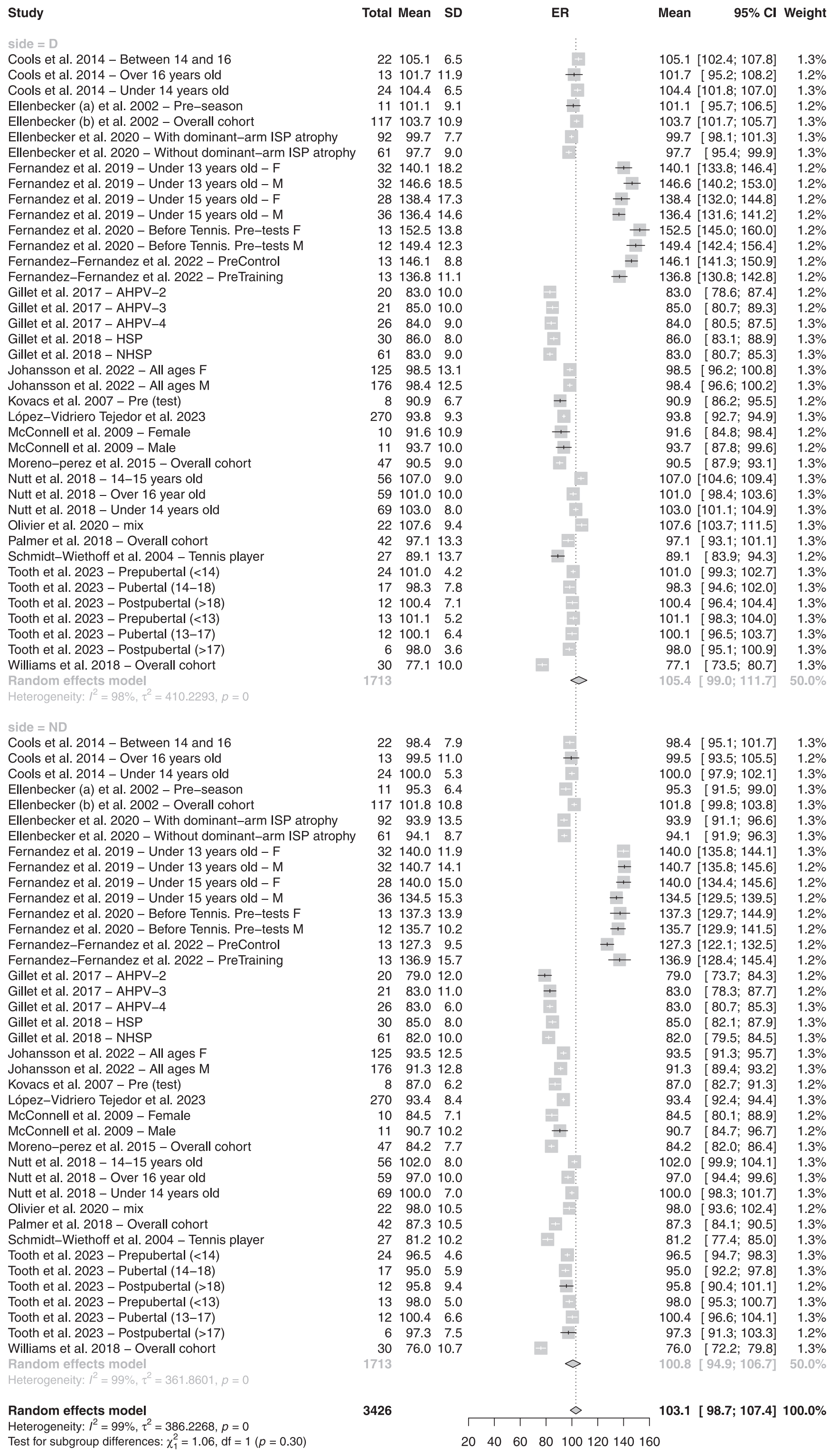


Figure 3 Forest plot comparing ER in dominant vs. nondominant side. *SD*, standard deviation; *CI*, confidence interval; *ER*, external rotation.

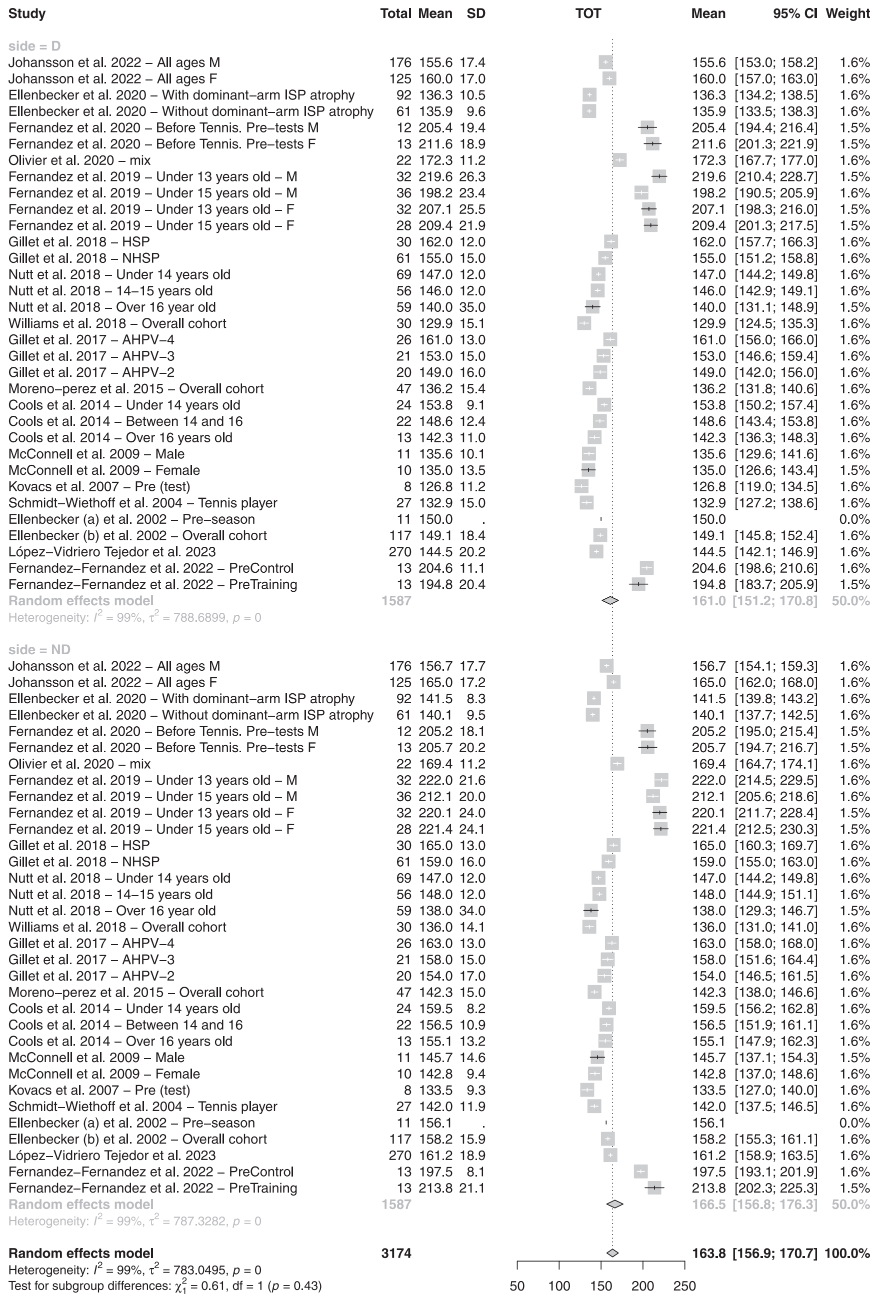


Figure 4 Forest plot comparing total ROM in dominant vs. nondominant side. *SD*, standard deviation; *CI*, confidence interval; *ROM*, range of motion.

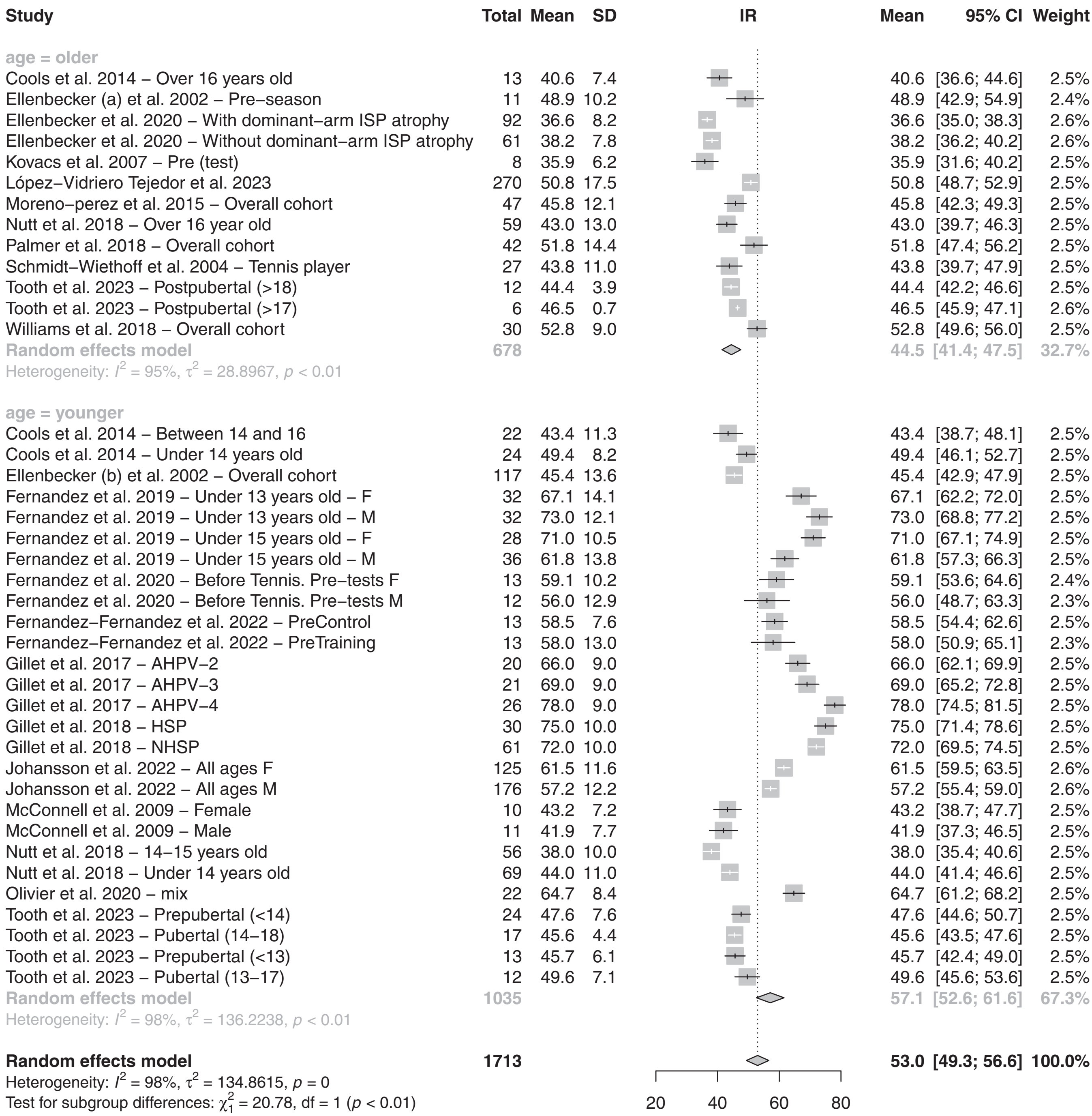


Figure 5 Forest plot comparing IR in older vs. younger tennis players. *SD*, standard deviation; *CI*, confidence interval; *IR*, internal rotation.

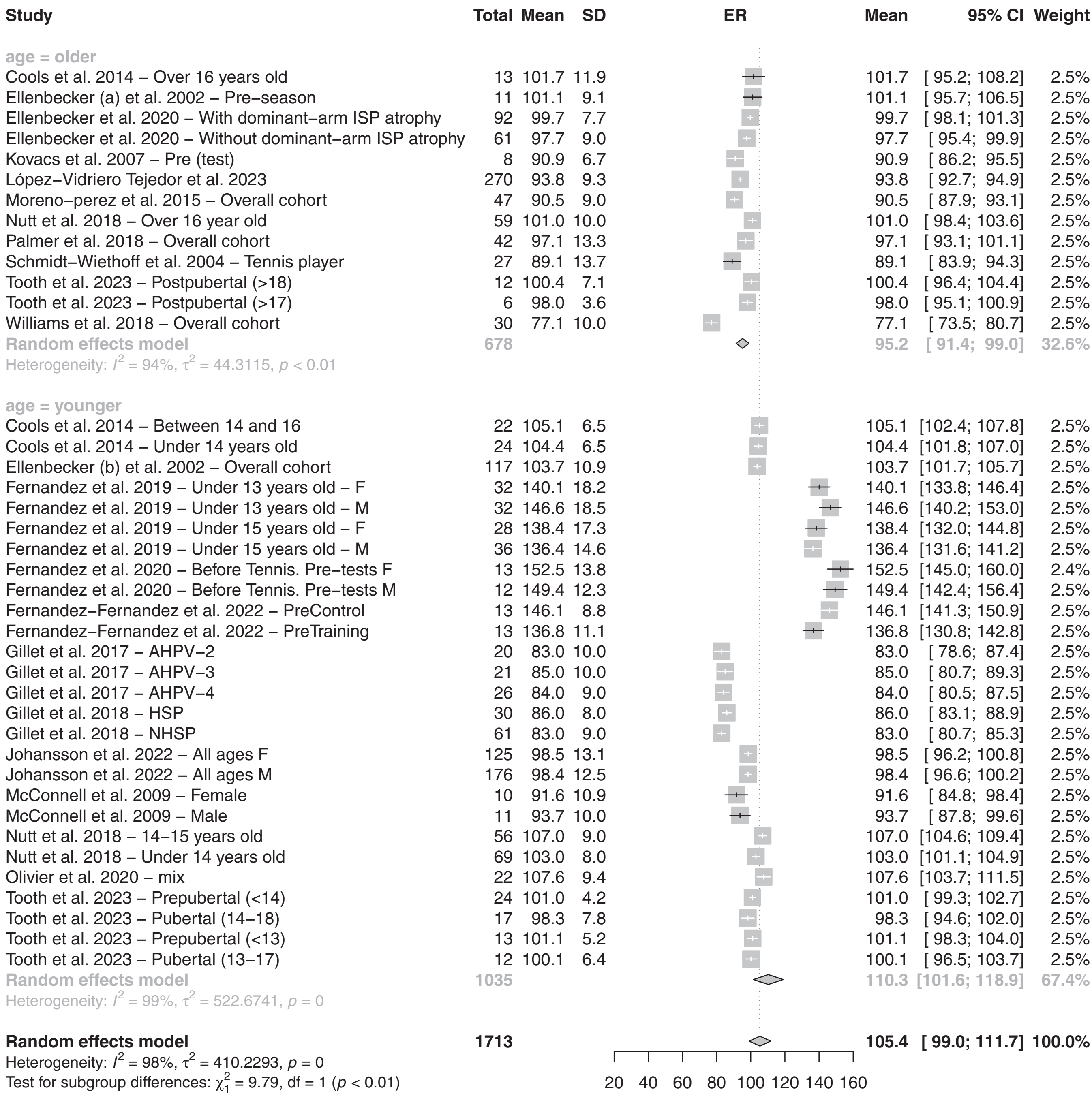


Figure 6 Forest plot comparing ER in older vs. younger tennis players. *SD*, standard deviation; *CI*, confidence interval; *ER*, external rotation.

Study	Total	Mean	SD	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 atrophy	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%
Moreno–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	.	150.0		0.0%
López–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 = younger						
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%
Olivier 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 years 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 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%
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%
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%
Ellenbecker (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			170.8	[159.5; 182.1]	71.8%
Heterogeneity: $I^2 = 98\%$, $\tau^2 = 753.0341$, $p < 0.01$						
Random effects model	**1587**			**161.0**	**[151.2; 170.8]**	**100.0%**
Heterogeneity: $I^2 = 99\%$, $\tau^2 = 788.6899$, $p = 0$						
Test for subgroup differences: $\chi^2_1 = 32.43$, df = 1 ($p < 0.01$)						

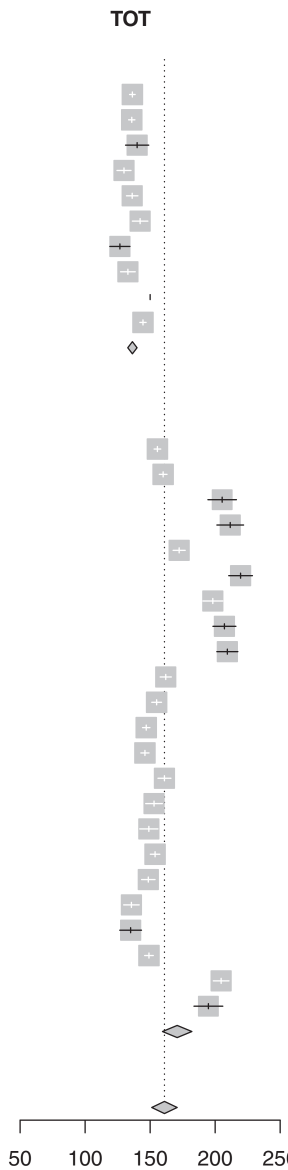


Figure 7 Forest plot comparing total ROM in older vs. younger tennis players. *SD*, standard deviation; *CI*, confidence interval; *ROM*, range of motion.

Dominant vs. nondominant

Comparing dominant vs. nondominant shoulders revealed that dominant shoulders had significantly smaller IR (53.0°, CI, 49.3-56.6; $I^2 = 98\%$, vs. 62.6°, CI, 58.7-66.5; $I^2 = 99\%$) (Fig. 2). However, there were no significant differences in ER (105.4°, CI, 99.0-111.7; $I^2 = 98\%$ vs. 100.8°, CI, 94.9-106.7 $I^2 = 99\%$) (Fig. 3), or total ROM (161.0°, CI, 151.2-170.8; $I^2 = 99$ vs. 166.5°, CI, 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°, CI, 41.4-47.5; $I^2 = 95\%$ vs. 57.1°, CI, 52.6-61.6; $I^2 = 98\%$) (Fig. 5), ER (95.2°, CI, 91.4-99.0; $I^2 = 94\%$ vs. 110.3°, CI, 101.6-118.9; $I^2 = 99\%$) (Fig. 6), and total ROM (136.4°, CI, 132.8-139.9; $I^2 = 86\%$ vs. 170.8°, CI, 159.5-182.1; $I^2 = 98\%$) (Fig. 7).

Females vs. males

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

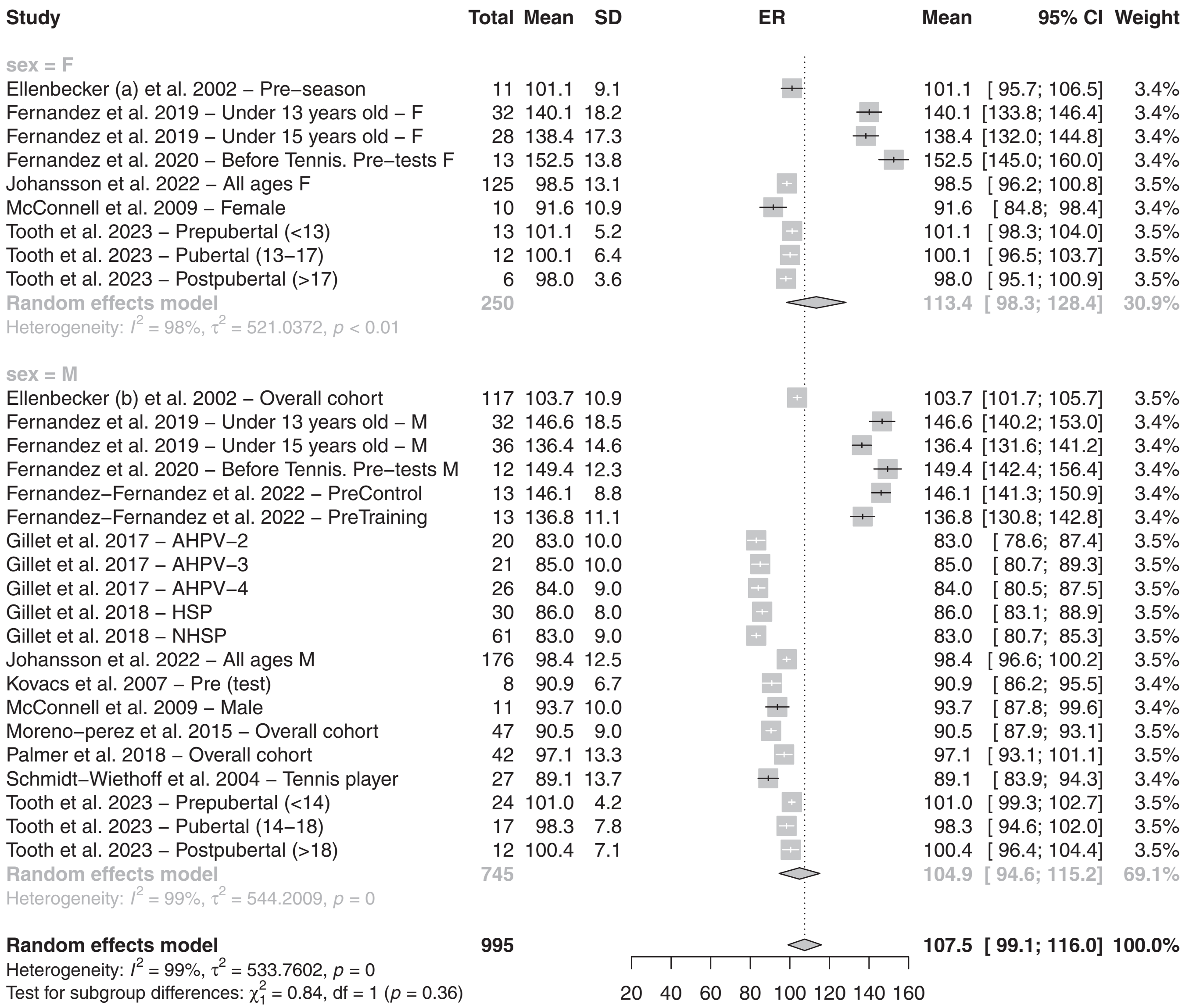


Figure 8 Forest plot comparing ER in females vs. males. *SD*, standard deviation; *CI*, confidence interval; *ER*, external rotation.

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

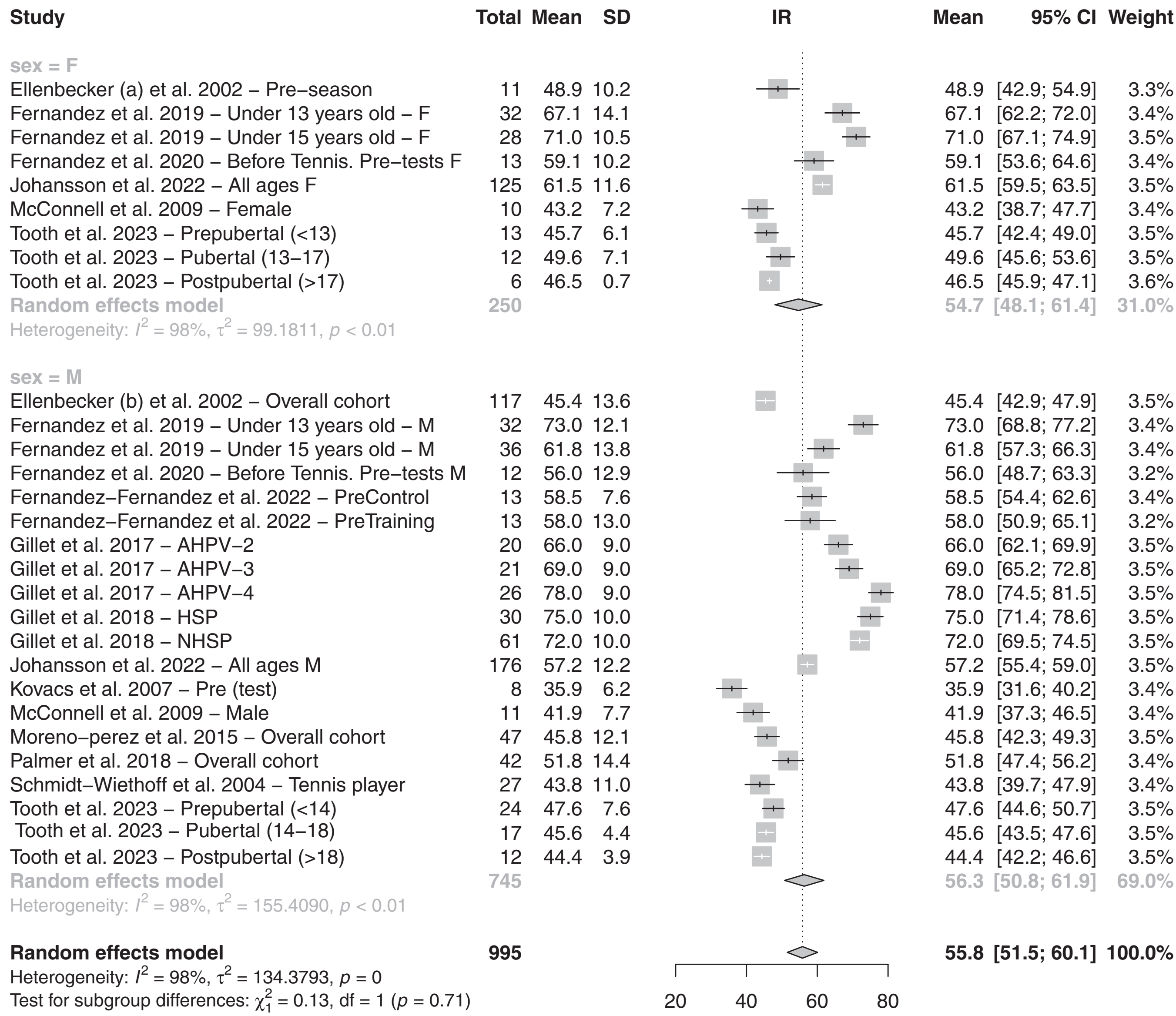


Figure 9 Forest plot comparing IR in females vs. males. *SD*, standard deviation; *CI*, confidence interval; *IR*, internal rotation.

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.[6,13,16,38] 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[31] 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[31] 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,

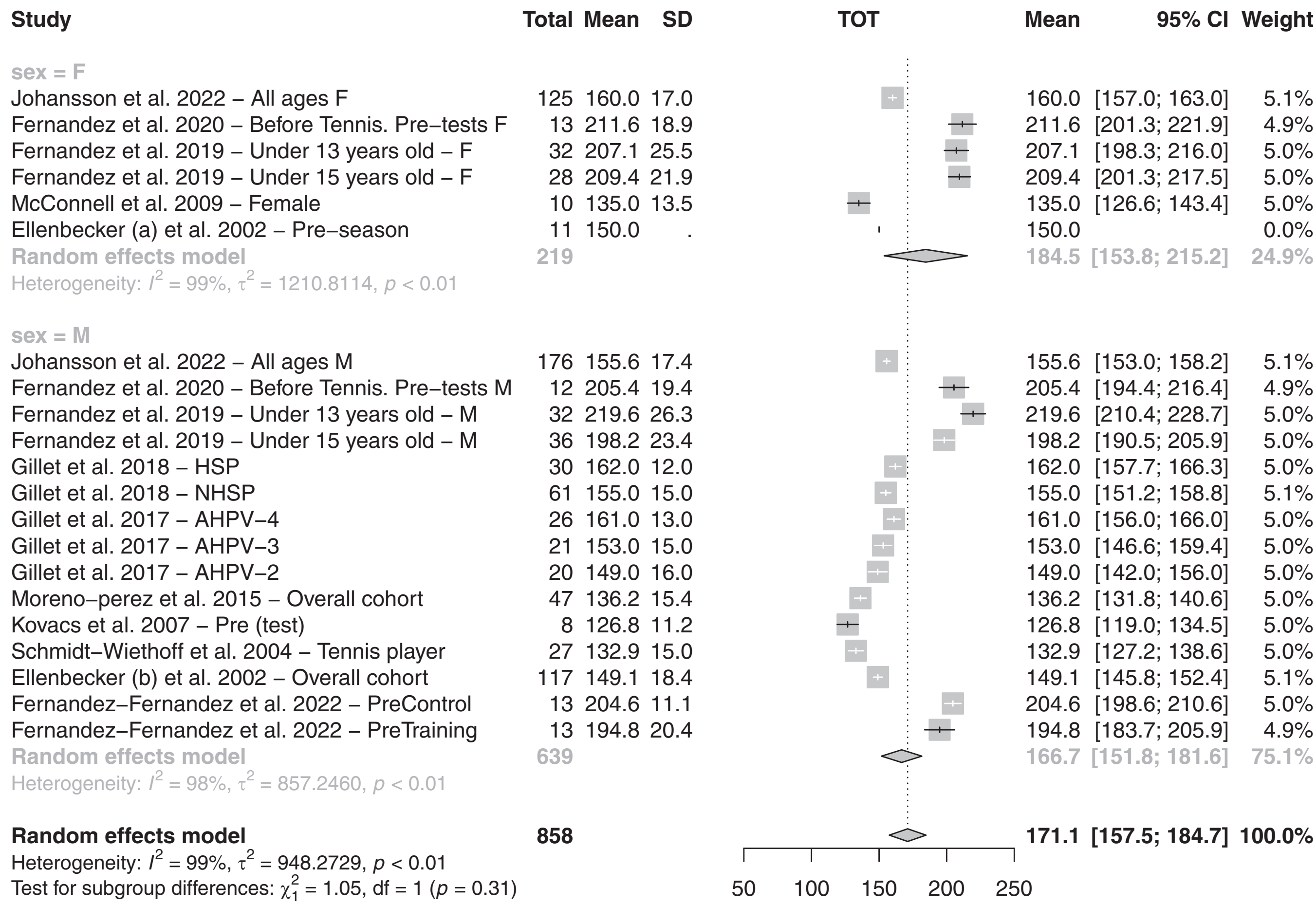


Figure 10 Forest plot comparing total ROM in females vs. males. *SD*, standard deviation; *CI*, confidence interval; *ROM*, range of motion.

when comparing injured to noninjured shoulders. This was further corroborated in a recent systematic review by Pozzi et al,[32] 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[32] 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:

Funding: ELSAN provided funding for statistical analysis and manuscript preparation.
Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not

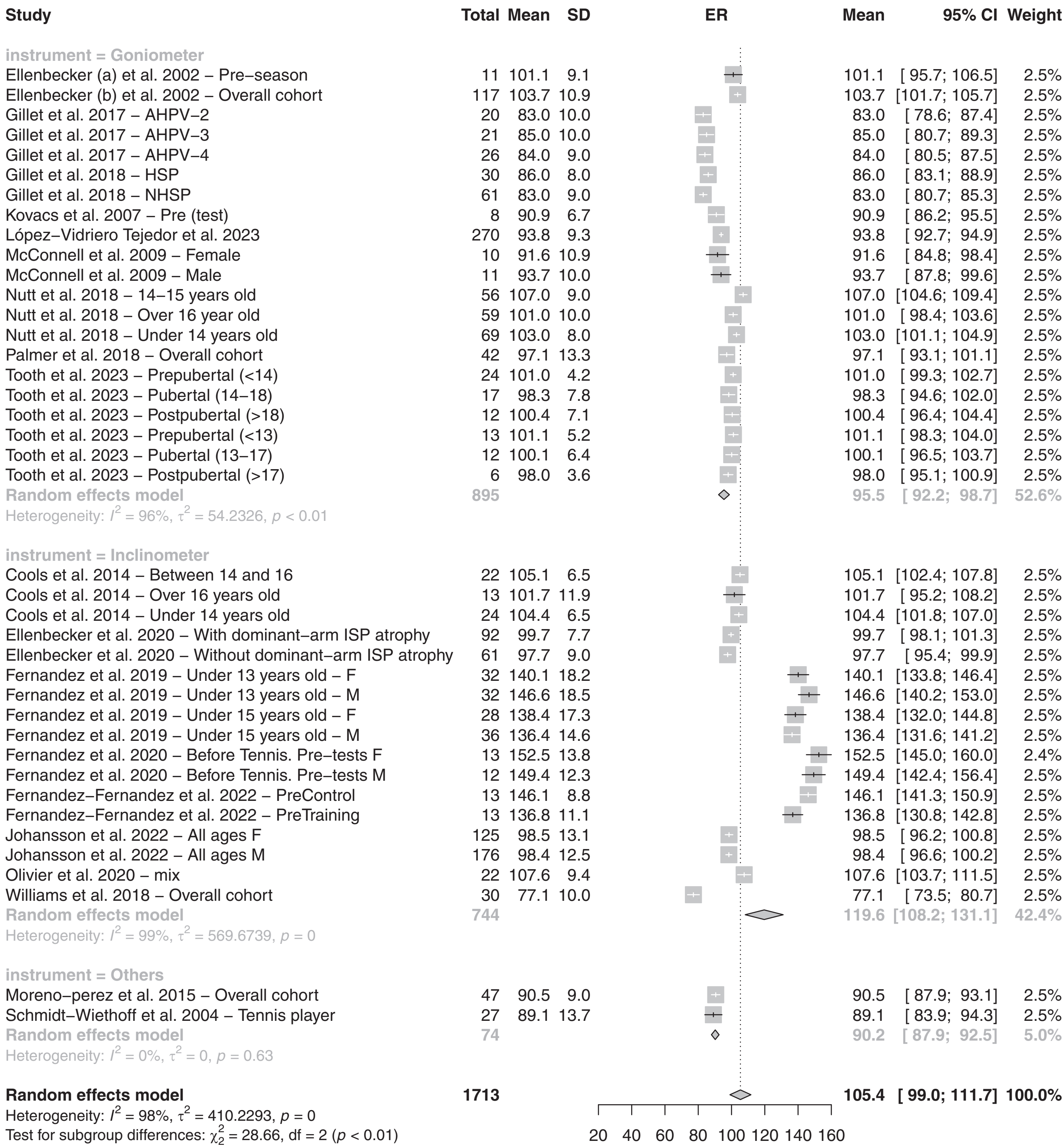


Figure 11 Forest plot comparing ER considering type of measurement. *SD*, standard deviation; *CI*, confidence interval; *ER*, external rotation.

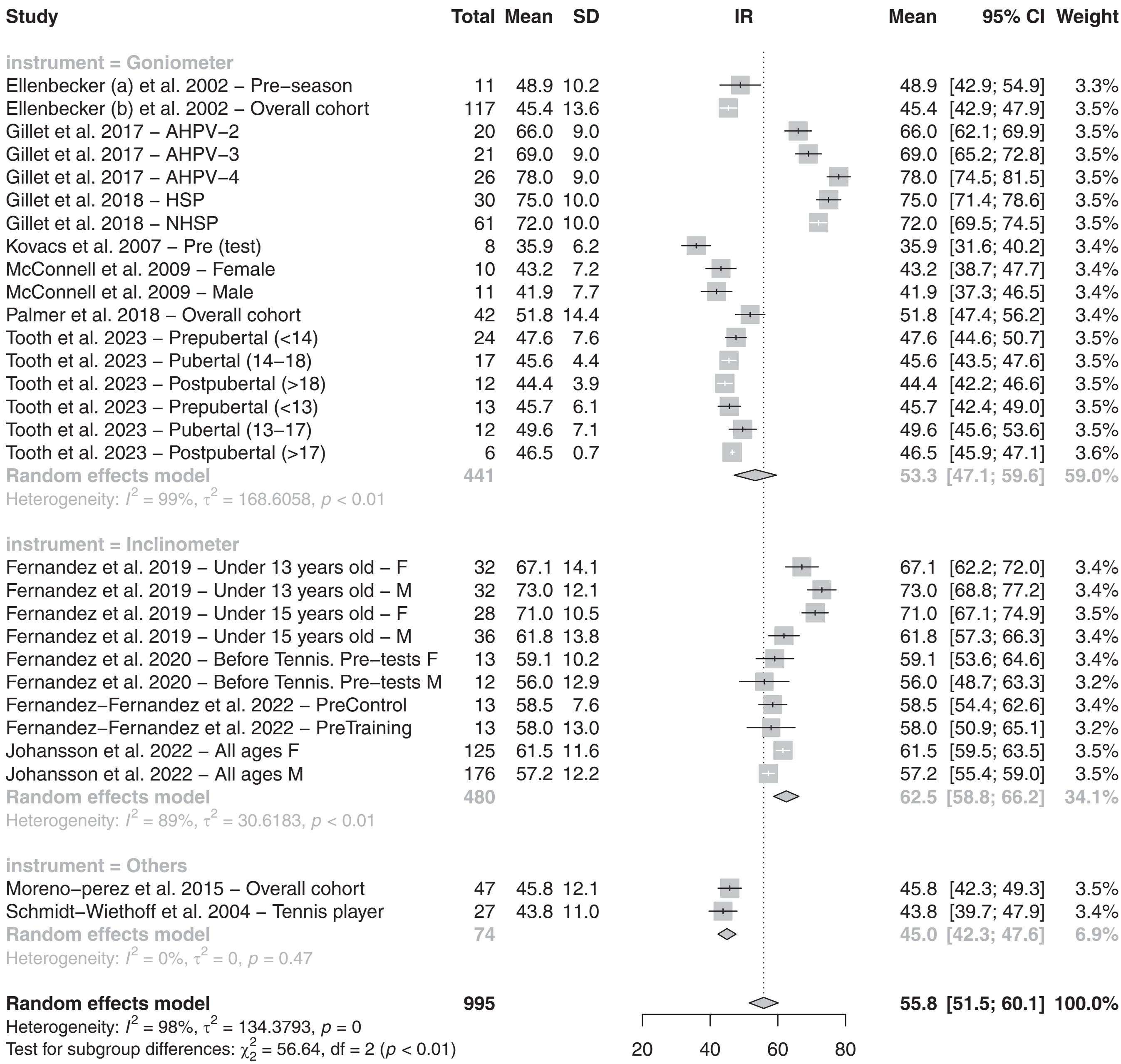


Figure 12 Forest plot comparing IR considering type of measurement. *SD*, standard deviation; *CI*, confidence interval; *IR*, internal rotation.

Study	Total	Mean	SD	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	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 years old – F	28	209.4	21.9	209.4	[201.3; 217.5]	3.1%
Williams et al. 2018 – Overall cohort	30	129.9	15.1	129.9	[124.5; 135.3]	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%
Cools et al. 2014 – Over 16 years old	13	142.3	11.0	142.3	[136.3; 148.3]	3.1%
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	744			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: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.37$						
Random effects model	**1587**			**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 ($p < 0.01$)						

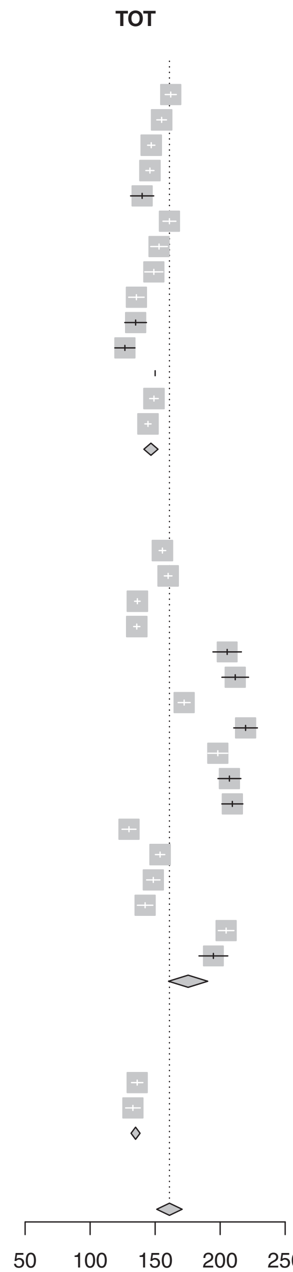


Figure 13 Forest plot comparing total ROM considering type of measurement. *SD*, standard deviation; *CI*, confidence interval; *ROM*, range of motion.

received any financial payments or other benefits from any commercial entity related to the subject of this article.

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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