IJSPT
INTERNATIONAL JOURNAL OF SPORTS PHYSICAL THERAPY

Leahy I, Florkiewicz E, Shotwell MP. Isokinetic Dynamometry for External and Internal Rotation Shoulder Strength in Youth Athletes: A Scoping Review. *IJSPT*. 2024;19(12):1521-1531. doi:10.26603/001c.125765

Scoping Review

Isokinetic Dynamometry for External and Internal Rotation Shoulder Strength in Youth Athletes: A Scoping Review

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Keywords: Isokinetic dynamometry, shoulder, youth, overhead athlete, external rotation, internal rotation, strength, peak torque

https://doi.org/10.26603/001c.125765

International Journal of Sports Physical Therapy

Vol. 19, Issue 12, 2024

Background

Accurately measuring shoulder strength in overhead athletes is critical, as sufficient strength is essential for safe and sustained performance during repetitive athletic movements. Isokinetic dynamometry (ID) offers dynamic strength assessments that surpass the capabilities of static methods, such as manual muscle testing and handheld dynamometry. The dynamic assessment provided by ID may enhance upper extremity evaluation, aiding in the prediction of injury risk and the determination of return-to-sport criteria for overhead athletes.

Purpose

The purpose of this review was to examine the existing literature concerning the application of isokinetic shoulder strength testing in rehabilitation and clinical decision-making processes among youth athletes who perform repetitive overhead activities.

Study Design

Scoping review

Methods

A comprehensive literature search was conducted using PubMed and EBSCO Host databases, covering publications from 2000-2024. Search terms included "isokinetic dynamometry," "shoulder," and "youth athlete." Inclusion criteria focused on youth athletes (<18 years) engaged in overhead sports, excluding those with neurological conditions or those designated as college or professional athletes. The PRISMA-ScR guidelines were followed.

Results

A total of 23 articles met the inclusion criteria. Volleyball and swimming were the most studied sports, with the most common testing position being the seated 90/90 position. Variations in testing speeds and outcome measures, such as peak torque and external rotation (ER) ratios, were identified.

Conclusions

Isokinetic dynamometry is a valuable tool for assessing shoulder strength in youth overhead athletes. It provides critical insights into muscle strength dynamics, aiding in injury prevention and rehabilitation. Further research is needed to optimize strength

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assessment protocols and enhance clinical decision-making for safe return-to-sport practices.

BACKGROUND

Within a larger framework in the decision process for return to sports, recommendations for overhead athletes are reported considering normalized shoulder strength and scapular mechanics, range of motion (ROM), and successful completion of a plyometric program.[1] However, many clinicians find it challenging to accurately measure shoulder strength due to limitations in equipment and expertise.

Shoulder strength assessment generally consists of isometric testing in neutral positions via manual muscle testing (MMT), handheld dynamometry (HHD), or isokinetic dynamometry (ID). Normative values for external rotation (ER) and internal rotation (IR) strength using HHD has been obtained in healthy adults,[2,3] and physically active collegiate male and females.[4] Studies indicate that HHD provides an assessment of shoulder IR/ER strength assessment that is highly correlated to assessments performed with ID.[5] The concern, however, with MMT and HHD testing is that reliability of these methods is highly dependent on clinician size and strength.[6] Additionally, because the testing position is static, HHD lacks the assessment of dynamic components associated with upper extremity movements required during overhead sports.[7] In addition to torque output as a measure of strength, ID can capture endurance deficits and strength ratio imbalances which are predictors of shoulder injury.[8] Ellenbecker demonstrated a significant difference in bilateral IR and ER strength measures between MMT grades and isokinetic dynamometry, widely recognized as the gold standard for measuring muscle strength and muscle endurance.[9]

Understanding the balance between the strength of agonist and antagonist muscles is crucial in evaluating and rehabilitating overhead athletes due to the intricate muscular activation patterns necessary for stability of the glenohumeral joint.[7] One strategy for strength testing of the shoulder in multiple positions throughout the range of motion is ID. Multiple authors have reported normative isokinetic strength assessment data for athletes involved in judo,[10] tennis,[11,12] badminton,[13,14] and volleyball.[15] In baseball, isokinetic strength testing has been performed in high school athletes,[16] collegiate athletes,[17,18] and professional athletes,[19] yet limited information is available regarding normative values of isokinetic shoulder strength in youth athletes.

Gaps remain in the literature, particularly regarding the establishment of normative values for younger, skeletally immature athletes and how these values differ across various stages of development. The purpose of this review was to examine the existing literature concerning the application of isokinetic shoulder strength testing in rehabilitation and clinical decision-making processes among youth athletes who perform repetitive overhead activities.

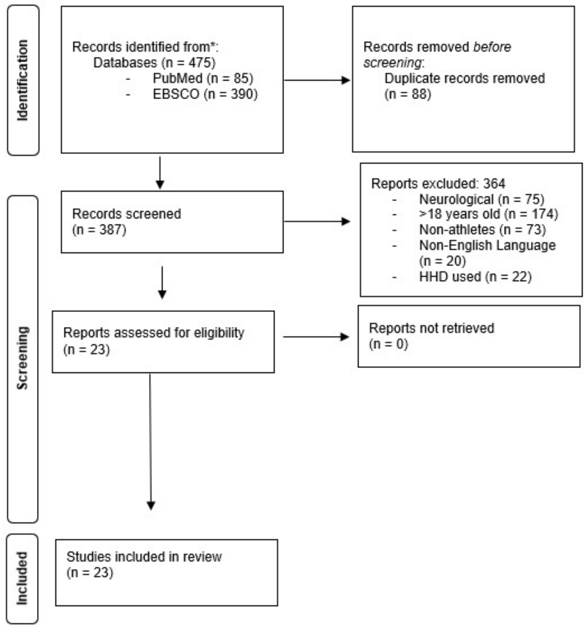

Figure 1. PRISMA flow diagram showing the literature search, screening, and eligibility results.

METHODS

This literature review was conducted in accordance with the recommendations of the "Preferred Reporting Items for Systematic Reviews and Meta Analysis extension for Scoping Reviews (PRISMA-ScR).[20]

SEARCH STRATEGY

The literature review was performed with the databases PubMed, and EBSCO Host, which provides a range of databases, e-journals and e-books. Search terms included in the search strategies included phrases such as: “isokinetic dynamometry AND shoulder,” “isokinetic dynamometry AND shoulder AND youth athlete.” (See Appendix A for full search criteria). The search was limited to full-text available human research published between 2000-2024, including participants ages <18 years associated with an organized, overhead sport, and published in the English language. Exclusion criteria were articles pertaining to any neurological condition, and athletes designated as collegiate or professional.

RESULTS

Electronic database searches identified 475 total studies. The scoping review included 23 studies[21-43] after duplicate removal, title/abstract screen, and full text review.

The PRISMA diagram (Figure 1) outlines the search process in its entirety.

Table 1. Use of Isokinetic Dynamometry (ID) in Various Sports and ID Equipment Parameters

Author	Sample / (Mean Age)	Sport	Type of Dynamometer	Position
Batalha N[21]	25 males (13.28 yrs)	Swimming	Biodex System-3	Seated 90/90 position
Batalha NM[24]	36 males (14.25 yrs)	Swimming	Biodex System-3	Seated 90/90 position
Batalha N[23]	40 males (14.65 yrs)	Swimming	Biodex System-3	Seated 90/90 position
Batalha NM[25]	40 males (14.65 yrs)	Swimming	Biodex System-3	Seated 90/90
Batalha N[22]	49 males (14.48 yrs)	Swimming	Biodex System-3	Seated 90/90
Clements AS[26]	18 males (13-16 yrs)	Baseball	Biodex Multi-Joint Dynamometer	Seated 90/90
de Lira CAB[27]	28 males (15.5 yrs)	Volleyball	Biodex System-3	Seated (angle not specified)
Dupuis, C[28]	10 males (15.87 yrs)	Baseball	Kin-Com	Seated 90/90
Duzgun I[29]	24 athletes (14.5 yrs)	Volleyball	Isomed 2000 Dynamometer	Seated 90/90 position
Eshghi S[30]	32 males (17.5 yrs)	Volleyball	Biodex System-4	Seated position 90 degrees abduction / 30 degrees shoulder flexion
Guney H[31]	65 athletes (16.1 yrs)	Volleyball & Basketball	Isomed2000 D&R	Seated 90/90
Lee DR[32]	23 males (18.2 yrs)	Baseball	Biodex Isokinetic Machine	Seated 90/90 position
Mascarin NC[33]	26 females (15.3 yrs)	Handball	Biodex Isokinetic Machine	Not Discussed
Mascarin NC[34]	39 females (15.3 yrs)	Handball	Biodex Isokinetic Dynamometer	Seated 90/90
Mickevičius M[35]	14 boys (11-12 yrs)	Baseball	Biodex System-3	Seated 90/90
Mohamed IW[36]	16 males (14.8 yrs)	Weightlifting	Multi Joint System-3 Pro	Seated 45/90 position Repeat testing done @ 90/90
Mulligan IJ[37]	39 males (15.36 yrs)	Baseball	Kin-Com Dynamometer	Seated: 90 degrees elbow flexion / 30 degrees abduction in scapular plane
Pawlik D[38]	12 females (12-13 yrs)	Volleyball	Multi-joint 4 Dynamometer Biodex	Seated 90/90
Pontaga I[39]	14 males (14.6 yrs)	Handball	REV-9000	Seated 90/90 position
Saccol MF[40]	40 athletes (14 yrs)	Tennis	Cybex-6000	Supine 90/90
van Cingel R[41]	40 females (17.6 yrs)	Handball	2-Humac Norm dynamometer	Supine 90/90
Vodička T[42]	20 males (13.23 yrs)	Tennis	Human Norm CSMI	Supine 90/90 position
Yildiz Y[43]	40 males (17.2 yrs)	Volleyball, Handball, Tennis	Cybex Norm	Supine 90/90

ISOKINETIC DYNAMOMETRY (ID) IN YOUTH REPETITIVE OVERHEAD ATHLETES

Of the included studies, volleyball was the most common overhead sport where ID was used for assessment.[27,29-31,38,43] The second most common sport was swimming[21-25] followed by handball,[33,34,39,41,43] baseball,[26,28,32,37] tennis,[40,42,43] weightlifting,[36] and basketball.[31] In the articles that fit the inclusion criteria, two pertained to symptomatic patients,[31,35] whereas the remaining articles looked at isokinetic normative values, or the effects of repetitive sport specific movements. Table 1 describes the use of ID in various sports along with the variety of parameters used for testing ID.

ISOKINETIC TESTING POSITION

Testing positions throughout studies varied, but trends are seen when testing the upper extremity (UE) of youth athletes with ID as illustrated in Table 1. The most utilized testing position for shoulder IR/ER is the seated position with the shoulder abducted to 90 degrees and the elbow flexed to 90 degrees, commonly known as the 90/90 position. It is postulated that this position, more than the arm at a neutral position, specifically addresses muscle function often required for an overhead athlete.[44] The use of the 90/90 position also demonstrates strong intraclass coefficient for test/re-test reliability.[45] Ellenbecker has discussed using a modified position of 30 degrees shoulder abduction, 30 degrees shoulder forward flexion, and 30 degrees diagonal tilt of the dynamometer to determine tolerance of the UE strength test prior to using the ID at a 90/90 position.[7] Additional alterations to the 90/90 positions used in research are the seated 90/30 (90 degrees elbow flexion and 30 degrees shoulder abduction),[37] seated 90/45 (90 degrees elbow flexion and 45 degrees shoulder abduction),[36] seated 90/30 with 90 degrees of shoulder abduction and 30 degrees of shoulder flexion,[30] and the 90/90 supine position.[40-43]

SPEEDS USED FOR TESTING

Table 2 provides information regarding the variations in the speeds used for testing youth athletes. Most studies assessed participants at multiple speeds for different outcome measures or for different sports-related contexts. Common speeds for assessment of isokinetic peak torque both concentrically and eccentrically include 60 deg/sec,[22-25,27,29,30,32-34,38-41] 90 deg/sec,[28,31,37,39,43] 120 deg/sec,[26,36,41] 180 deg/sec,[21-25,28-30,32,37,38,40,42] 240 deg/sec,[27,33,34,36,39] 300 deg/sec,[38,42] and 360 deg/sec.[36]

OBJECTIVE MEASURES FROM ISOKINETIC DYNAMOMETRY

PEAK TORQUE

In many studies pertaining to the use of ID in youth athletes, peak torque, normalized via body weight, was the primary objective measure.[26,27,29,40] Peak torque is then used to compute measures of bilateral symmetry, using left and right values, and unilateral strength ratios using shoulder external and internal rotation strength values. Research indicates that repetitive sports-related movements lead to discernible discrepancies in peak torque between shoulder external rotation (ER) and internal rotation (IR) strength when comparing the dominant and non-dominant arms in athletes. Repetitive motions during youth sports such as volleyball,[27,38,43] swimming,[21-25] and tennis[40] result in increased IR peak torque in the dominant arm of the athlete. Variations exist among age groups within the same sport as evidenced by youth handball athletes demonstrating higher ER and IR peak torque in the dominant arm compared to non-dominant arm in athletes with a mean age of 17.6 years.[41] Conversely, younger players (mean age of 14.6 years) showed no statistically significant difference between ER and IR peak torque.[39] In a study of healthy teenage baseball players, Dupuis found greater concentric ER strength in the dominant arm at speeds of 90°/sec and 180°/sec.[28] In contrast, Mickevičius observed decreased ER strength among younger baseball players (average age 11.6 years) who had a history of shoulder pain.[35] It has been hypothesized that differences in peak torque output results in higher likelihood of overuse type injuries in youth athletes.[24,27,41]

ER:IR RATIO

Eight studies[21-25,35,40,42] used concentric external rotation to concentric internal rotation strength ratios during for their objective measurements whereas six studies[28,30,31,34,41,43] investigated various forms of eccentric to concentric ratios between ER and IR.

Comparison of shoulder agonist and antagonist muscle groups helps identify specific muscular imbalances.[7] Variations in the dominant arm's external rotation to internal rotation (ER:IR) ratios are frequently observed, particularly in cases where imbalances occur in the shoulder's agonist-antagonist muscle relationships. These imbalances can signify weaknesses that heighten athletes' vulnerability to injury.[24,40] Ideal ER:IR has been defined as 66%, which remains constant throughout the velocity spectrum[46]; however, this ratio is described in skeletally mature athletes.[7]

A common theme in youth overhead athletes is decreased ER:IR ratio in the dominant arm[21-24,34,40-42] due to the theorized increase in IR peak torque because of sport specific repetitive motion. Although these imbalances do not result in changes in athletic performance, there is fear that if not addressed in the younger athlete they can result in overuse type injury.[40]

There are unique variations of the ER:IR used in ID assessment of youth athletes as evidenced by discussion of ER:IR acceleration and ER:IR deceleration described by Yildiz in youth volleyball players.[43] The concept eccentric to concentric ER:IR is defined as the ratio of balance for muscle activity where the shoulder medial rotators eccentrically control external rotation, while lateral rotators eccentrically control internal rotation, ensuring optimal shoulder function.[47] This explanation is similar to Dupuis' definition of Dynamic Control Ratio (DCR) in youth baseball players.[28] Both Yildiz and Dupuis investigate the eccentric and concentric relationship of the ER:IR ratio of the shoulder. In each case, the ER:IR ratio into the acceleration phase (concentric ER to eccentric IR) was observed to be higher in the dominant arm,[28,43] whereas the ER:IR ratio into the deceleration phase (eccentric ER to concentric IR) is lower in the dominant arm of the youth volleyball athlete,[43] but no difference existed in the youth baseball athlete.[28]

DISCUSSION

This scoping review highlights the use of isokinetic dynamometry of the youth overhead athlete to obtain multiple objective measures. In adolescent overhead athletes, the repetitive nature of sport-specific movements imposes unique demands on the dynamic muscular control of the glenohumeral joint. This demand is highlighted by fluctuations in the external rotation to internal rotation peak torque ratio, a phenomenon hypothesized to significantly impact the vulnerability of the shoulder complex to injury.[21-25] Various studies support this hypothesis, including symptomatic athletes[35] and those with glenohumeral internal rotation deficits.[31]

In sports like baseball, dynamic muscular control of the glenohumeral joint is essential, particularly given the substantial stress experienced across the upper extremity joints during pitching. The angular velocities of shoulder internal rotation and elbow extension can range from 1,000

Table 2. Isokinetic Dynamometry Testing Speed and Other Objective Measures

Author	Testing Speed	Objective Measures
Batalha N[21]	60 deg/sec 180 deg/sec	• PT IR • PT ER • ER:IR ratio
Batalha N[24]	60 deg/sec 180 deg/sec	• PT • ER/IR ratio
Batalha N[23]	60 deg/sec 180 deg/sec	• Max torque • ER/IR ratio - norm is 66-75%
Batalha N[25]	60 deg/sec 180 deg/sec	• PT • ER/IR ratios
Batalha N[22]	60 deg/sec 180 deg/sec	• PT • ER/IR ratio
Clements AS[26]	120 deg/sec	• PT/BW
de Lira CAB[27]	60 deg/sec 240 deg/sec	• Absolute PT • Relative PT (divided by BW) • Absolute total work • Relative total work (divided by BW) • Conventional strength ratio • Functional strength ratio
Dupuis, C[28]	90 deg/sec 180 deg/sec	• PT • IR con / ER ecc (performance ratio) • ER con / IR ecc (cocking ratio)
Duzgun I[29]	60 deg/sec 180 deg/sec	• PT / BW • Total work
Eshghi S[30]	60 deg/sec 180 deg/sec	• FDR • EReccn:IRcon
Guney H[31]	90 deg/sec	• ER:IR • Max eccentric ER torque / Max concentric IR torque
Lee D[32]	60 deg/sec 180 deg/sec	• PT
Mascarin N[33]	60 deg/sec 240 deg/sec	• PT and total work
Mascarin N[34]	60 deg/sec 240 deg/sec	• at 60 deg/sec: • IR PT • CR (ER con / IR con) • at 240 deg/sec • IR PT • IR avg power • FR (ER ecc / IR con) • ER PT was measured at both speeds
Mickevičius M[35]	120 deg/sec	• PT • ER:IR ratio
Mohamed IW[36]	120 deg/sec 240 deg/sec 360 deg/sec	• Relative PT • Time to PT
Mulligan I[37]	90 deg/sec 180 deg/sec	• PT and Total work for both movements at both speeds
Pawlik D[38]	60 deg/sec 180 deg/sec 300 deg/sec	• Concentric IR PT
Pontaga I[39]	60 deg/sec 90 deg/sec	• PT • Avg power

Author	Testing Speed	Objective Measures
	240 deg/sec	
Saccol M[40]	60 deg/sec 180 deg/sec	• PT / BW • Total work / BW • ER/IR ratio
Vodička T[42]	180 deg/sec 300 deg/sec	• Peak torque • ER/IR ratio
Yildiz Y[43]	90 deg/sec	• ER ecc / IR con • ER con / IR ecc • Both in the late cocking phase of overhead motion and the deceleration phase

Key: PT= peak torque, ER= external rotation, IR= internal rotation, BW= body weight, CR= cocking ratio, FDR= functional deceleration ratio, FR= functional ratio, DCR= dynamic control ratio, CON = concentric, ECC = eccentric

deg/sec to 7,200 deg/sec in youth and collegiate pitchers, respectively, from maximum external rotation through the acceleration phase.[48,49] While ID testing velocities of 240 deg/sec do not fully replicate these speeds, they still yield valuable data on shoulder musculature function at higher isokinetic speeds.[50] Table 3 provides a detailed breakdown of these different sport-specific findings.

GAPS IN THE LITERATURE

ID studies of youth athletes skew towards specific sports such as volleyball and swimming. Limited information is available regarding the use of ID for assessment of athletes participating in youth baseball. In reviewing the ages of participants recruited for ID articles in youth athletes, the youngest subjects were 11 years old. However, pitching and repetitive throwing in baseball often begins as early as 6-7 years of age. Studies included in a systematic review suggest that starting repetitive pitching at 10 years of age or younger increases the risk of upper extremity-related injury.[51] In most sports, children are playing and specializing in sport positions at a much younger age than captured in this review, but changes in shoulder IR strength between dominant and non-dominant arm has been seen in youth throwers under the age of 10 using HHD.[52] Understanding dynamic strength values and muscular balance relationships with measurements from ID in skeletally immature athletes and the changes that occur with repetitive overhead motions can assist in developing injury prevention, rehabilitation programs, and return to sport decision making for youth throwing athletes.

LIMITATIONS

Only studies in English languages were included in the review and the range of articles searched were between 2000-2024. Also, no quality assessment of the studies was performed, which may limit the impact of the findings.

CONCLUSION

Isokinetic dynamometry as an assessment in youth overhead athletes provides insights into shoulder strength (torque) and strength ratios. There is variety in the assessment parameters utilized in the included studies of youth athletes in various sports. By precisely evaluating isokinetic strength, clinicians can gauge the shoulder's dynamic control, facilitating the tailored design of training programs. Isokinetic assessments allow for detailed analysis of power and the balance between agonist and antagonist muscle groups during movement, enabling the identification of specific strength impairments and guiding targeted interventions to enhance upper extremity loading tolerance for repetitive overhead activities.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest related to the content of this manuscript.

Submitted: June 19, 2024 CST, Accepted: September 17, 2024 CST

Table 3. Sports Specific Isokinetic Dynamometry (ID) Strength Findings

SPORT	STUDY	ID SPORT SPECIFIC STRENGTH OUTCOMES
Volleyball	De Lira[27]	• Higher IR peak torque in dominant arm
	Duzgun[29]	• ER strength increased with weighted jump rope in dominant arm
	Esghi[30]	• Functional Deceleration Ratio (eccentric to concentric strength of IR and ER) in dominant arm • Increased ER:IR ratio after strengthening program
	Pawlik[38]	• Higher IR peak torque in dominant arm
Swimming	Batalha[21]	• Higher IR peak torque in dominant arm
	Batalha[22]	• Decreased ER:IR ratio in dominant arm in swimmers vs control • Higher IR peak torque in swimmer dominant arm
	Batalha[23]	• Decreased ER:IR ratio in dominant arm for swim only group
	Batalha[24]	• Decreased ER:IR in dominant arm for swimmers- • Higher IR peak torque in dominant arm for swimmers
	Batalha[25]	• Decreased ER:IR in dominant arm for swimmers • Training improved ER peak torque in dominant arm
Baseball	Clements[26]	• Peak torque of dominant arm not associated with throwing velocity
	Dupuis[28]	• Higher ER peak torque in dominant arm • ER:IR lower in dominant arm • ER concentric :IR eccentric in cocking phase was higher in dominant arm • ER eccentric:IR concentric during deceleration was no different side to side
	Lee[32]	• IR and ER peak torque increased with CKC strengthening in dominant arm
	Mickevičius[35]	• ER eccentric strength was weaker in baseball players dominant arm • Decreased ER:IR in dominant arm for baseball players with pain • IR eccentric: IR concentric – lower in dominant arm • ER eccentric: IR concentric – lower in dominant arm • ER concentric: IR eccentric – lower in dominant arm
	Mulligan[37]	• Decreased ER:IR ratio in the dominant arm • No significant difference between eccentric and concentric peak torque between dominant vs non-dominant arm
Handball	Mascarin[33]	• ER:IR lower in dominant arm • ER eccentric : IR concentric was lower in dominant arm • ER:IR ratio unchanged in dominant arm with strength training
	Mascarin[34]	• All participants demonstrated weak IR of the dominant arm • ER:IR – 82.8 in experimental group vs 77.6 in control group • Strength testing did not result in improvement in IR strength • Strength training did not improve strength ratios • Strength training improved average power
	Pontaga[39]	• No statistically significant differences between dominant and non-dominant arm peak torque • Average power of IR was higher in dominant arm
	Van Cingel[41]	• ER:IR lower in dominant arm of handball players • Higher ER and IR peak torque in dominant arm
Tennis	Saccol[40]	• Decreased ER:IR on dominant arm • Higher ER strength in youth male tennis players • Higher IR strength on dominant arm for both youth male and female athletes
	Vodička[42]	• Decreased ER:IR ratio on dominant arm • Higher ER strength in dominant arm • Higher IR strength on dominant side
Weightlifting	Mohamed[36]	• ER:IR ratio of dominant arm improved with isokinetic strength program • ER:IR ratio of dominant arm improved with isotonic strength program • IR and ER peak torque of dominant arm increased in both training groups

Key: ER= external rotation, IR= internal rotation

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SUPPLEMENTARY MATERIALS

Appendix A

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