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Title	The Association Between Grip Strength and Isometric Mid-Thigh Pull
	Performance in Elite Footballers
Туре	Article
URL	https://clok.uclan.ac.uk/id/eprint/37119/
DOI	https://doi.org/10.1016/j.scispo.2021.03.007
Date	2022
Citation	Rhodes, David, Jeffery, Josh, Carling, Christopher, Mawene, Youl and Alexander, Jill (2022) The Association Between Grip Strength and Isometric Mid-Thigh Pull Performance in Elite Footballers. Science and Sports. ISSN 0765-1597
Creators	Rhodes, David, Jeffery, Josh, Carling, Christopher, Mawene, Youl and Alexander, Jill

It is advisable to refer to the publisher's version if you intend to cite from the work. https://doi.org/10.1016/j.scispo.2021.03.007

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1	Title
2	The Association Between Grip Strength and Isometric Mid-Thigh Pull Performance in Elite Footballers
3	
4	Titre
5	Association entre force de préhension et tirage isométrique mi-cuisse pour des footballeurs de haut
6	niveau.
7	
8	Brief Running Head
9	Grip Strength Isometric Mid-Thigh Pull Elite Footballers
10	
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37	Funding
38	No funding was received for this research.
39	
40	Declaration of interest statement
41	The authors report no conflict of interest.
42	
43	
44	Abstract
45	
46	Objectives: The purpose of the present study was to analyse the association between grip strength and
47	performance of the standardised protocol of the isometric mid-thigh pull (IMTP) test.
48	
49	Methods: 31 elite premier league footballers completed test-retest measures of peak force (PF) grip
50	strength and IMTP, measures were taken 7 days apart. Post completion of the test-retest 3 maximal
51	IMTP and bilateral grip strength measures were taken. Mean PF was calculated bilaterally for each
52	assessment. Linear relationships were determined for test-retest and Grip Strength Test (GST) and
53	IMTP PF output.
54	
55	Results: Test-retest of the GST and IMTP displayed significant almost perfect correlations bilaterally
56	$(p \le 0.001, r = 0.92 - 0.94, CI = 0.85 - 0.96)$. Bilateral moderate-large significant correlations were
57	also identified between grip strength and IMTP PF ($p \le 0.05$, $r = 0.54 - 0.72$, CI = 0.30 - 0.86).
58	
59	Conclusions: GST and IMTP are reliable and repeatable measures. Findings in the present study
60	indicate consideration must be given to the influence of grip strength on maximal IMTP PF output.
61	Previous literature describes standardisation procedures for IMTP performance. Pre-completion of
62	IMTP measures in elite footballers, performance practitioners should consider assessment of the
63	athlete's grip strength despite the use of lifting straps.
64	
65	Key words: soccer, conditioning, injury risk, screening, assessment
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76 Abstrait

77 Objectifs : Le but de cette étude était d'analyser l'association entre la force de préhension (ou force de grippe) et les performances sur un test standardisé de tirage isométrique mi-cuisse (TIMC).

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Méthodes : 31 joueurs de football haut niveau de Premier League prirent part à un test-retest mesurant
la force maximum (FM) de grippe et de tirage isométrique à mi-cuisse, enregistrés à 7 jours d'intervalle.
À la suite du test-retest, 3 mesures maximales de TIMC et de force de grippe bilatérale furent retenues.
La moyenne de FM bilatérale fut calculée pour chaque évaluation. La relation linéaire fut déterminée
entre le test-retest ; et entre la force de grippe et le tirage isométrique mi-cuisse.

85

86 **Résultats** : Les test-retest de force de grippe et de TIMC bilatérale ont montré, respectivement une 87 corrélation significative presque parfaite ($p \le 0.001$, r = 0.92 - 0.94, CI = 0.85 - 0.96). La FM de grippe 88 et le TIMC bilatérale ont aussi montré une corrélation significative modérée à large ($p \le 0.05$, r = 0.5489 - 0.72, CI = 0.30 - 0.86).

90

91 Conclusions : La force de grippe et le TIMC sont des mesures fiables et reproduisibles. Les résultats 92 de l'étude ici présente, indiquent que l'influence de la force de grippe sur les performances maximales 93 de TIMC doit être considérée. La standardisation des procédures de TIMC est précédemment décrite 94 dans la littérature. Préalable a des mesures de TIMC pour des footballeurs élites, préparateurs physiques 95 devraient considérer l'évaluation de la force de préhension des athlètes, quand bien même ils 96 utiliseraient des sangles.

97

- 98 Mots clés : football, conditionnement physique, risque de blessure, évaluation.
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109 INTRODUCTION

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Injury risk factors in football are quantifiable via a battery of tests, with maximal strength commonly 111 reported and performed by practitioners to determine a player's readiness to train or return to functional 112 activity post injury^{1,2}. Quantifying strength output within elite athletic populations provides 113 114 contemporary debate amongst practitioners with regards to the type of test, timing of test within a training week and metrics utilised. Literature has highlighted several forms of strength measures, which 115 include repetition max (RM), eccentric, concentric and isometric, to name a few^{3,4,5}. The diverse nature 116 of the equipment utilised to determine strength output also poses a predicament for sports performance 117 118 practitioners, with decisions drawn on the sensitivity of the test and reliability of measures taken⁶. 119 Debate surrounding the type of strength testing selected in an elite performance environment should 120 consider the following factors: relationship to mechanisms of common injuries, transferability of the 121 information to performance and potential detrimental effects of the test on the athlete⁷.

122

123 Concentric tests have been criticised in literature for not replicating muscular demand during functional performance and have limited association with the mechanisms of injury associated with common 124 injuries in football, i.e. hamstrings^{8,9}. Utilisation of RM testing has been documented as transferable to 125 performance and literature has demonstrated its reliability¹⁰. The fatiguing nature of determining an 126 127 individual's RM however is a concern for practitioners and utilised within a normal training week could potentially increase injury risk¹. Quantifying elite athlete's eccentric strength profile is a common 128 approach utilised within football⁸. This is due to its association with injury risk and functional 129 Literature has continuously highlighted the damaging nature of eccentric muscle 130 performance⁹. contractions^{11,12}, providing sports performance practitioners with the dilemma of how to incorporate 131 this muscle assessment when players are in competition, particularly within fixture congested periods¹³. 132 133

A contemporary alternative to quantify lower limb strength parameters in athletes is the isometric midthigh pull (IMTP)^{14,15}. Isometric strength testing is highly reliable, has low measurement error and variability^{4,6} and is less provocative than eccentric testing, thus reducing the risk of injury^{6,14,15}. In addition, IMTP testing has displayed strong correlations between short explosive sprints, representing an acceleration in football to press play and speed of change of direction¹⁶. Suggesting measures of 139 IMTP link closely with performance output. However, debate exists as to whether these performance 140 relationships exist between absolute or relative peak force (PF) measures^{17,18}. Literature also highlights 141 strong associations with dynamic strength exercises, indicating that the IMTP performance is a clear 142 indicator of strength output¹⁹. Early research identified issues surrounding standardisation of the 143 testing protocols within papers, but this was addressed by Comfort et al., (2019)¹. Key considerations 144 highlighted in the paper emphasised consideration of bar height, body position, grip width, foot position 145 and consistency of these measures within each lift the athlete completes.

146

147 Literature has discussed the use of lifting straps/athletic tape to reduce the effect of grip strength as a limiting factor^{20,21}. Although, it is noted that actual effect of grip strength when utilising the current 148 standardised protocol suggested by Comfort et al., (2019)¹, has not been analysed. Successful 149 completion of the IMTP requires the athlete to grip the bar and push as hard as possible with the legs to 150 151 generate force¹. Theoretically, requiring significant grip strength to be able to perform the IMTP effectively and produce maximal force. Reliance on lifting straps to successfully perform the lift would 152 potentially place excessive load through the wrist joint, causing discomfort to the athlete and thus the 153 154 potential to reduce force application. Examination of the relationship between grip strength and IMTP performance is limited within current literature. Although handgrip strength may not be directly 155 156 associated with usual characteristic assessment in footballers per se, determining whether grip strength 157 is a factor in IMTP performance may have implications on the output generated by the athlete when 158 performing a maximal IMTP test. Therefore, the aim of the present study is to determine the relationship 159 between the hand grip strength and IMTP in elite players within a premier league football club.

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161 METHODS

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Thirty-one elite U23 category 1-status academy male footballers from an English Premier League 165 Football Club completed the present study, age 20.98±2.49 years; height 183.40±8.93 cm and weight 166 77.65±8.38 kg. All players eligible for the study were in full training, free from injury and available 167 for competitive selection. Normal screening protocols completed at the club include completion of the 168 169 IMTP test, therefore each player has been exposed to the protocols completed in the present study. Players were advised to refrain from caffeine or additional supplement intake up to 24 hours prior to 170 data collection. This bout of testing was completed in a normal training week, mid-competitive season 171 172 when the players had returned post a recovery day. All participants provided written informed consent 173 in accordance with the department and host university faculty research ethics committees, and in 174 accordance with the Helsinki Declaration (2018).

175

¹⁶³ Subjects

176 Design

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178 This was an experimental study designed to investigate the reliability of grip strength test (GST) and standardised IMTP test in elite footballers. Further to this, the study analysed the linear relationships 179 between maximal grip strength on the IMTP peak force (PF) output of elite male footballers. All 180 subjects completed all testing within the study. Prior to any testing anthropometric data of each of the 181 athletes was taken and familiarisation trials of both the GST and standardised IMTP test were 182 completed. Week 1 subjects were asked to complete 3 maximal seated, elbow extended grip strength 183 measures utilising a hand-held dynamometer, followed by 3 maximal IMTP. This process was repeated 184 on week 2. Mean scores from each of the 3 lifts were then taken for analysis from each week. Each of 185 the familiarisation and testing sessions were separated by 7 days. Week 3 consisted of each athlete 186 completing 3 maximal grip strength measures and 3 maximal IMTP measures. Again, mean scores of 187 188 the 3 measures were taken for analysis and linear correlations were calculated for PF measures.

189

190 *Methodology*

191

192 Participants completed a familiarisation trial 7 days prior to testing to negate potential learning effects²². 193 This included completion of 3 maximal repetitions of the hand grip dynamometer (left and right) and 194 IMTP. Prior to any testing all participants completed the standardised dynamic warm up protocol 195 proposed by Comfort et al., (2019)¹, which consisted of 3 second repetitions of IMTP performance at 196 50%, 75% and 90% maximal efforts, each completed 60 seconds apart. All testing was completed between 13:00 and 17:00 hrs to account for the effect of circadian rhythm and in accordance with regular 197 competition times²³. Post familiarisation trials all participants completed a test-retest to determine the 198 199 reliability of measures on both the hand grip dynamometer and IMTP. Measures on both pieces of 200 equipment were completed on two separate occasions, with 7 days between test and retest to consider learning and fatigue effects²². On completion of the test-retest data collection, participants were again 201 given a further 7 days before completion of 3 maximal IMTP lifts and 3 maximal grip strength tests to 202 203 determine correlation.

204

All hand grip testing was completed with the same hand grip dynamometer (Jamar ® Hydraulic Hand Dynamometer (Model J00105) (Sammons Preston, Bolingbrook, Illinois)) adhering to ASHT (American Society of Hand Therapists) clinical assessment guidelines²⁴. The dynamometer was set at the second handle position for each participant. Each player sat in a straight-backed chair, with back supported and feet flat on the floor. The shoulder was adducted and neutrally rotated and forearm/wrist in neutral position. The elbow was extended to replicate the position it would be in when completing the IMTP, this position has previously shown excellent reliability²⁵. The dominant and non-dominant side were both subjected to 3 measures of maximal grip strength on the dynamometer, with the averageof the 3 combined scores utilised for analysis.

214

Completion of all IMTP testing followed the standardisation protocol¹. Measurements of PF were 215 obtained by completing the IMTP via a force platform (ForceDecks FD4000 (ValdPerformance, 216 Australia, 2018). Prior to completion of the IMTP correct body position for each participant was 217 determined and repeated for each test completed. Bar height was set to replicate the 2nd pull position 218 during the clean, adjusting to ensure that optimal knee (125-145°) and hip (140-150°) angles were set, 219 due to body position being shown to significantly affect force generation^{4,14,15, 26}. Angles were 220 quantified utilising a hand-held goniometer. The goniometer was placed on the lateral femoral condule. 221 222 with upper arm following the line of the femur and lower arm tracing the line of the fibula to quantify 223 knee angle. Hip angle was determined by placing the goniometer on the greater trochanter, with the 224 upper arm tracing the torso and lower arm the line of the femur.

225

Once angles of the two joints were determined, observation of the position of the athlete was made, 226 227 ensuring an upright torso with slight flexion of the knee and dorsiflexion of the ankle. Shoulder girdle 228 was retracted and depressed, with the shoulders above or slightly behind the vertical plane of the bar. 229 Feet were hip width apart and centred beneath the bar, with the thighs in contact with the bar. 230 Positioning of the athlete and a final assessment was completed to ensure they were in the correct 231 position and no tension was applied to the bar due to its negative effect on joint angle⁴. A record of 232 each participant's body position ensured consistency of testing within each repeated lift. During each lift completed athletes were secured to the bar with lifting straps placed around the wrists^{20,21}. 233

234

On the completion of each lift the athlete was provided with standardised instructions provided by the 235 club's strength and conditioning coach. These included pushing the feet as hard as possible in to the 236 237 ground; drive the feet in to the force platform not pulling the bar with the arms or rising on the toes; apply pretension to ensure correct body position and allow a pre-test force baseline (achieved by 238 observing the force trace to ensure it was consistent with body mass); provide a countdown of 3-2-1 239 Pull to initiate the IMTP to maximum. During the test the athlete was provided with verbal 240 encouragement²⁷, completing 3 successful maximal trials without any errors. Ensuring each trail was 241 within 250N of one another^{20,21}. 242

243

245

All participants completed 3 assessments on the hand GST and IMTP. Each assessment consisted of 3
repetitions within each test, with maximal grip strength and IMTP PF being ascertained. Mean force
for both GST and IMTP for both the left and right sides were taken for data analysis. Force data for

²⁴⁴ Statistical Analysis

both GST and IMTP were displayed as Newtons (N) and Peak Force (PF). These values were identifiedfor each participant and utilised for analysis.

251

Pearson's correlation coefficients were calculated to quantify the linear relationship between test-retest for both IMTP and GST. This was also completed to determine the linear relationship between GST and IMTP force outputs. All statistical analysis was completed using PASW Statistics Editor 25.0 for windows (SPSS Inc, Chicago, USA). Statistical significance was set at $P \le 0.05$. Coefficient of correlation (r) and respective level of significance (p value) describes total variance. The following criteria quantified magnitude of the correlation <0.1, trivial; >0.1 to 0.3, small; >0.3 to 0.5, moderate; >0.5 to 0.7, large; >0.7 to 0.9, very large; and >0.9 to 1.0, almost perfect.

260 RESULTS

261

Table 1 summarises the mean and standard deviation scores achieved for all metrics observed withinthe present study.

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Insert table 1 here

Test-retest of the GST displayed significant correlations for both the left ($p \le 0.001$, r = 0.92, CI = 0.88 - 0.96) and right hand ($p \le 0.001$, r = 0.93, CI = 0.89 - 0.97). Displaying almost perfect correlations between each test, indicating excellent test-retest reliability. The same was also noted for the IMTP test-retest when utilising Comfort et al., (2019) standardisation protocol. Bilaterally IMTP PF displayed significant correlations, left ($p \le 0.001$, r = 0.92, CI = 0.85 - 0.97) and right ($p \le 0.001$, r = 0.94, CI = 0.91 - 0.96).

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 *** Insert Table 2 Here ***

 274
 *** Insert Table 3 Here ***

275

Significant correlations displayed between GST, tested with the handheld dynamometer, and PF 276 ascertained via IMTP performance on the ForceDecks (Grip (L) and IMTP (L): $p \le 0.05$, r = 0.72, CI = 277 0.55 - 0.86 and Grip (R) and IMTP (R): p = 0.01, r = 0.54, CI = 0.30 - 0.77). Contralateral relationships 278 279 between grip strength and PF also displayed no significant correlation between Grip (L) and IMTP (R): p > 0.05, r = 0.22, CI = -0.19 - 0.62, but significant between Grip (R) and IMTP (L): $p \le 0.05$, r = 0.35, 280 CI = 0.12 - 0.60). Significant correlations were also displayed between GST (L) and (R) (p ≤ 0.001 , r 281 282 = 0.68, CI = 0.46 - 0.83). No significant correlations were displayed between IMTP (L) and IMTP (R), 283 (p > 0.05, r = -0.02, CI = -0.36 - 0.36).284 *** Insert Table 4 Here ***

285 ***Insert Figure 1 Here***

286

287 DISCUSSION

288

The aim of the present study was to ascertain the reliability of repeated measures of GST and IMTP 289 within an elite football population and to investigate the relationship between grip strength and IMTP 290 291 performance. PF measures within both tests were ascertained and utilised for comparison. The test-292 retests performed on both the GST and IMTP testing highlighted almost perfect correlations, suggesting both testing procedures were extremely reliable in this athletic population. These findings were 293 consistent with previous literature^{4,6}. Isometric contractions have been shown to be less damaging than 294 other methods of muscle assessment 6,14,15 . Thus, making them an attractive method of assessing a 295 player's readiness to train or injury risk, particularly in periods of competition or fixture congestion¹³. 296 PF measures ascertained from the IMTP test have been associated with measures of functional 297 performance¹⁶. Although, it is strongly debated that these PF measures are required to be relative to the 298 subject's weight^{17,18}. Absolute PF measures were taken within the present study, as the objective was 299 300 to ascertain whether grip strength still influenced force output when completing the IMTP despite the 301 use of the standardised protocol proposed by Comfort et al., (2019)¹. Sports performance practitioners 302 should carefully consider the metrics observed when completing the IMTP test when quantifying the 303 athlete's readiness to train, progression in rehabilitation or identification of injury risk.

304

305 Main findings from the present study highlight significant moderate to large correlations between players grip strength in relation to PF and their IMTP performance (0.54 - 0.72). It is suggested that 306 securing of the participants to the bar with lifting straps, may reduce the effect of grip strength on IMTP 307 performance, but it does not eliminate its effect, as suggested in earlier literature^{20,21}. Importantly, 308 findings from this current body of work indicate that grip effect can still not be discounted despite 309 utilisation of a standardised protocol¹. Poor grip strength when performing IMTP maximally may have 310 311 implications of loading through the wrist particularly when attached to the bar with lifting straps. The straps and load applied when performing the test may cause a distraction of the wrist, resulting in 312 discomfort to the athlete and thus reducing the amount of force applied. The effects of this could be 313 catastrophic in youth athletes with an immature skeleton²⁸. It must also be considered that athletes may 314 place less emphasis on gripping the bar due to the attachment of lifting straps. Either scenario could 315 316 potentially result in reduced/poor performance or injury risk.

317

Practitioners must be prudent to advise that despite the use of lifting straps athletes must apply maximal grip to the bar when performing. This approach should be considered in any standardisation protocol associated with the IMTP. Previous literature^{20,21} cited by Comfort et al., (2019)¹ identified the use of lifting straps, taping or a combination of both. Both papers described that the utilisation of these methods ensured that grip strength was not a limiting factor in the IMTP protocol. It is important to note that although these papers identified interclass correlation coefficients (ICC) scores for the described methods completed, they did not identify grip strength performance of the athletes. Comparisons were made between varying metrics associated with IMTP and a dynamic lift. Therefore, not allowing the assumption that grip strength was no longer a limiting factor. The present study directly identifies relationships between grip strength and IMTP performance. Further research in this area should consider ICC values of athletes performing IMTP with and without wrist support, but also compare outputs in relation to wrist support method utilised in the lift.

330

331 Recent studies indicate several positive reasons for utilising the IMTP test as a method of quantification to inform injury risk, readiness to train or play or a progression marker in rehabilitation^{29,30}. The 332 findings of the present study clearly support these earlier conclusions. Emphasis is placed on legs 333 334 pushing through the floor during performance of the IMTP to exert maximum output. Although the present study analyses the effect of grip strength it is important to appreciate that performance of the 335 IMTP requires stabilisation of the hips, as well as maintaining a good posture representative of the 336 second pull position. Any failure to maintain this throughout performance of the IMTP may result in 337 338 inaccurate outputs being produced. If the grip strength of the athlete is not adequate the athlete may 339 create pull from other areas of the body, meaning an adjustment of the position described in the methods of the current and previous papers^{1,4}. It is important to emphasise to the athlete or practitioners the 340 341 effect inadequate grip application may have on performance. Thus, highlighting that pre performance 342 of this test practitioners may consider performance of a GST.

343

344 *Limitations:*

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The present study identifies relationships between grip strength and IMTP performance. Limitations 346 exist within the present body of work, most notably failure to consider other metrics exhibited during 347 the IMTP test. Future work in this area could consider other performance metrics exhibited in the IMTP 348 349 test like rate of force development (RFD), another metric like PF that has been strongly associated within literature with functional performance¹. Positioning of the athletes during testing was 350 standardised in relation to protocols described in previous work, but the effect of poor positioning was 351 352 not quantified¹. Further research should consider the effect poor grip strength may have on the athletes 353 positioning when performing the IMTP test. Consideration must also be given to other limiting factors 354 associated with the performance of the IMTP, which may include reduced dorsiflexion of the ankle or poor shoulder and shoulder girdle function. Sports performance practitioners need to consider the 355 356 importance of these factors and appropriately screen the athlete to ensure optimal performance can be 357 achieved when completing the IMTP test.

358

359 PRACTICAL APPLICATIONS

360	
361	• Consideration must be given to the effect of grip strength on IMTP performance when utilised
362	as a test to quantify maximum PF in elite footballers.
363	• Although grip strength has implications on maximum PF output, the IMTP test still represents
364	a reliable and repeatable test for quantifying PF output in elite footballers.
365	• Careful consideration should be given to assessing the grip strength of the athlete pre
366	completion of the standardised protocol for IMTP test.
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368	APLICATIONS PRATIQUES
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370	• L'effet de la force de grippe sur les performances de TIMC doit être considéré dans un test de
371	force maximal pour des joueurs élites de football.
372	• Bien que la force de grippe soit impliquée dans la force maximal produite, le TIMC reste un
373	test fiable et reproduisible pour la quantifier la force maximale de joueurs élites de football.
374	• L'évaluation de la force de grippe des athlètes préalablement a un test standardise de TIMC
375	devrait être considérée avec attention.
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379	CONCLUSIONS
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381	The findings of the present study suggest that grip strength has an influence on IMTP test performance.
382	The importance of a standardised protocol has previously been identified and should continually be
383	utilised within IMTP testing within elite sports performance environments. Although it is important for
384	practitioners to consider the assessment of an athlete's grip strength pre a maximum PF test. Further
385	research should consider the utilisation of quantifying maximum PF output with the IMTP. Thought
386	should be given to analysing grip strength and other quantifiable measures of lower limb PF.
387	
388	CONCLUSIONS
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390	Les résultats de l'étude ici présente suggèrent que la force de grippe a une influence sur les performances
391	de test de TIMC. L'importance d'un protocole standardise a déjà été identifié précédemment, et devrait
392	continuer à être utiliser pour le test TIMC dans le contexte de la performance sportive de haut niveau.
393	Il est toutefois important pour les préparateurs physiques de considérer l'évaluation de la force de grippe

des athlètes avant un test maximal de TIMC. Davantage d'études devraient considérer l'utilisation de
quantifier les mesures maximales de force de TIMC. Une attention particulière devrait être donnée à
l'analyse de la force de grippe et autres mesures quantifiables de la force maximale des membres
inférieurs.

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