

# INVESTIGATING RELIABILITY AND VALIDITY OF THE TESTS OF CHANGE OF DIRECTION AND REACTIVE AGILITY IN PATIENTS AFTER KNEE SURGERY

# ISPITIVANJE POUZDANOSTI I VALJANOSTI TESTOVA PROMJENE SMJERA KRETANJA I REAKTIVNE AGILNOSTI KOD PACIJENATA NAKON OPERACIJE KOLJENA

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**Abstract:** Agility is one of the key performance factors important for prevention of falls. There is a lack of tests applicable for testing agility in untrained, older and clinical populations. The aim of this research was to investigate the reliability and validity of the newly-designed testing protocol of change of direction speed (CODS) and reactive agility (RAG) in the clinical population. Research comprised 25 individuals older than 40 years of age who underwent knee surgery. Variables included age, gender, anthropometric characteristics, RAG, and CODS tests. Results displayed new tests as being reliable among patients after knee surgery. Also, tests were valid with regard to body mass and age (with better results in younger and lighter participants). Participants achieved similar results in CODS and RAG, with strong correlation between tests, which implies that CODS and RAG represent similar abilities in this population. Future studies should investigate the metric characteristics of here proposed tests in other subsamples.

**Keywords:** motor capacities, change of direction, injury, clinical population, adults.

**Sažetak:** Agilnost je jedna od ključnih sposobnosti važnih za redukciju padova. Međutim, nedostaju testovi koji su primjenjivi za ispitivanje agilnosti kod netrenirane, starije i kliničke populacije. Cilj ovog istraživanja je bio ispitati pouzdanost i valjanost novih testova promjene smjera kretanja (change of direction speed-CODS) i reaktivne agilnosti (RAG) kod kliničke populacije. U istraživanju je sudjelovalo 25 osoba starijih od 40 godina koji su imali operaciju koljena. Varijable su uključivale dob, spol, antropometrijske karakteristike, te rezultate u novim testovima agilnosti. Rezultati su prikazali da su novi testovi agilnosti pouzdani za ispitivanje agilnosti kod pacijenata nakon operacije koljena. Testovi su se prikazali valjanima u smislu diferenciranja ispitanika prema dobi i tjelesnoj težini (mlađi ispitanici i lakši ispitanici su postizali bolje rezultate kod oba testa). Ispitanici su u oba testa postizali podjednake rezultate i rezultati su visoko povezani, što ukazuje da testovi RAG i CODS kod ove populacije predstavljaju slične sposobnosti. Buduća istraživanja bi trebala ispitivati metrijske karakteristike predloženih testova kod drugačijih podskupina ispitanika.

**Ključne riječi:** motoričke sposobnosti, promjena smjera kretanja, ozljede, klinička populacija, odrasli.

## INTRODUCTION

Agility in the context of sport is defined as the rapid whole-body movement with a change of direction and speed in response to an external stimulus. There are two basic forms of agility: change of direction and speed (CODS) and reactive agility (RAG) (Sheppard & Young, 2006). In CODS testing protocols, the individual is already acquainted with a particular direction of movement while in RAG the individual is not familiar with the task and

## UVOD

Agilnost se u kontekstu sporta definira kao brzi pokret tijela s promjenom smjera i brzine kao odgovor na određeni podražaj. Postoje dva oblika agilnosti: brzina promjene smjera kretanja (CODS) i reaktivna agilnost (RAG) (Sheppard & Young, 2006). Kod CODS pojedinac unaprijed zna u kojem će smjeru trebati promijeniti kretanje, dok kod RAG pojedinac treba promijeniti smjer kretanja kao odgovor na vanjski podražaj koji nije una-

have to react and change the direction of movement in response to an external stimulus (e.g. visual, acoustic, the trajectory of the ball, opponents changes of direction during the game). Previous studies have identified various factors affecting agility, testing methods, and agility training (Krolo et al., 2020; Paul, Gabbett, & Nassis, 2016). However, most conducted research has focused on professional athletes rather than the untrained population.

Agility is considered a crucial ability in preventing falls in untrained individuals (Davis, Donaldson, Ashe, & Khan, 2004). Consequently, agility was observed as the ability and potential of a person to rapidly change the motor pattern due to adjusting to the newly formed situation. For instance, changing the walking pattern and movement direction to avoid obstacles such as house furniture or objects on the ground (Miyamoto et al., 2008). Fall injuries are well-known to be in common, especially in the elderly and untrained individuals who are fragile and have impaired musculoskeletal system (Fhon, Rodrigues, Neira, Huayta, & Robazzi, 2016). Therefore, the requisite for conducting agility-related research has been warranted in both untrained and elderly populations (Davis et al., 2004). The authors of this study have previously emphasized the importance of agility in the elderly population and the development of specific tests that will represent real-life situations (Sekulić & Foretić, 2019). There are only a few studies on agility tests in untrained and elderly populations. One of those studies that investigated the reliability and validity of the Ten Step Test in the elderly concluded that the test was reliable and could predict the risk of falling (Miyamoto et al., 2008). Also, the "Agility test for Adults" design and developed for the untrained population were reliable and applicable for agility test assessment (Manderoos et al., 2016). Likewise, a reactive agility test intended for the elderly has present appropriate reliability and constructive validity differentiating groups by age (Sobolewski, Thompson, Conchola, & Ryan, 2018). Regarding agility training, research by Reed-Jones, Dorgo, Hitchings, and Bader (2012) was concluded that agility training with an emphasis on visual training may be beneficial for preventing falls in the untrained elderly population. It is obvious that only several studies have conducted research on agility in the untrained and elderly population. As far as familiar to authors, very few studies have investigated the reliability and validity of tests that are adapted to real-life situations in the untrained clinical population. Therefore, the aim of this study was to assay the reliability and validity of newly constructed agility tests for individuals after knee surgery.

prijed poznat. Brojna istraživanja su identificirala različite faktore koji utječu na agilnost, metode testiranja i treniranja agilnosti (Krolo et al., 2020; Paul, Gabbett, & Nassis, 2016). Međutim, većina istraživanja su se fokusirala na profesionalne sportaše, a ne na netreniranu populaciju.

Agilnost se smatra sposobnošću koja je ključna kod prevencije padova kod netreniranih osoba (Davis, Donaldson, Ashe, & Khan, 2004). U ovom smislu, agilnost je promatrana kao sposobnost brze promjene motoričkog obrasca uslijed promjene situacije. Primjerice, promjena obrasca i smjera hodanja zbog izbjegavanja prepreka kao što su pokušstvo ili predmeti na tlu (Miyamoto et al., 2008). Poznato je da su ozljede uslijed padova česte, posebice kod starijih i netreniranih osoba koje imaju slabiji i manje razvijen mišićno-koštani sustav (Fhon, Rodrigues, Neira, Huayta, & Robazzi, 2016). Stoga, uočila se potreba za istraživanjem agilnosti i kod netrenirane i starije populacije (Davis et al., 2004). Autori ove studije su već prije naglašavali važnost agilnosti kod starije populacije i razvoj specifičnih testova koji će predstavljati stvarne životne situacije (Sekulić & Foretić, 2019).

Postoji nekoliko istraživanja na testovima agilnosti kod netrenirane i starije populacije. Istraživanje u kojem je ispitana pouzdanost i valjanost testa agilnosti (Ten Step Test) kod starijih osoba je zaključilo da je test pouzdan i da može predvidjeti rizik od pada (Miyamoto et al., 2008). Slično, test „Agility test for Adults“ namijenjen netreniranoj populaciji se pokazao pouzdanim i primjenjivim za testiranje agilnosti (Manderoos et al., 2016). Isto tako, test neplanirane agilnosti namijenjen starijim osobama je pokazao primjerenu pouzdanost i konstruktivnu valjanost između različitih dobnih skupina (Sobolewski, Thompson, Conchola, & Ryan, 2018). Što se tiče treniranja agilnosti, istraživanje od Reed-Jones, Dorgo, Hitchings, and Bader (2012) je zaključilo kako treniranje agilnosti s naglaskom na vizualni trening može biti korisno za preveniranje padova kod netrenirane starije populacije.

Očito je kako se jako malo istraživanja bavilo istraživanjem agilnosti kod netrenirane i starije populacije. Koliko je autorima poznato, jako su rijetka istraživanja ispitivala pouzdanost i valjanost testova koji su prilagođeni uobičajenim životnim situacijama kod netrenirane kliničke populacije. Stoga, cilj ovog istraživanja je bio ispitati pouzdanost i valjanost novokonstruiranih testova agilnosti kod osoba nakon operacije koljena.

## METHODS

### Participants

The study comprised 25 untrained individuals older than 40 years ( $56.3 \pm 18.5$  years). Respondents were patients who participated in a rehabilitation program after arthroscopic knee surgery and total knee arthroplasty. Rehabilitation was conducted at the Clinical Medical Center in Osijek, Croatia. The inclusion criteria for respondents was the ability to walk 100 meters and sit up and get up from the seat without knee pain. Participants were informed of the objective, risks, and protocol of the study prior to the start of the study.

### Variables

Variables included age, gender, anthropometric characteristics (body height, body mass), CODS, and RAG tests.

Testing of CODS and RAG was performed using original equipment based on ATMEL microcontroller (model AT89C51RE2; ATMEL Corp, San Jose, CA, USA). An infrared sensor (IR) was used as the external measurer, and LED lights were used as controlled outputs. Respondents for the RAG test started from a standing upright position. They had to step out with the preferred foot, after that the IR signal would be intersected which initiated the time measurement and ignition on one of the LED lights located in the cone placed under the seat. The respondents had to perceive which cone was illuminated, walk to a certain seat, sit down, get up, return to the starting line as fast as possible, turn around and repeat the same moving form. When respondents have intersected the IR signal on the fourth return, time stopped. Respondents were not informed of the ignition order, and three different test scenarios were performed (different order of cones illumination). CODS testing protocols were performed on the same polygon, but the respondents were informed in advance of the cones illumination order (Figure 1).

## METODE RADA

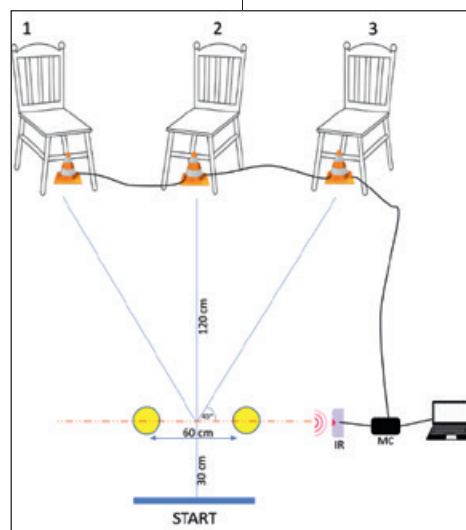
### Ispitanici

Istraživanje je uključivalo 25 netreniranih osoba starijih od 40 godina ( $56,3 \pm 18,5$  godina). Ispitanici su bili pacijenti koji su sudjelovali u rehabilitacijskom programu nakon artroskopske operacije koljena i potpune artroplastike koljena. Rehabilitacija se odvijala u Kliničkom medicinskom centru u Osijeku, Hrvatska. Svi ispitanici su trebali biti u stanju prošetati 100 metara te sjesti i podići se sa sjedalice bez boli u koljenu. Sudionici su bili obaviješteni o cilju, rizicima i protokolu ispitivanja prije početka istraživanja.

### Varijable

Varijable su uključivale dob, spol, antropometrijske karakteristike (tjelesna visina, tjelesna masa), CODS i RAG testove.

Testiranje CODS i RAG se odvijalo koristeći uređaj na osnovi ATMEL mikrokontrolera (model AT89C51RE2; ATMEL Corp, San Jose, CA, SAD). Infracrveni senzor (IR) se koristio kao vanjski vremenski okidač, a LED svjetla su korištena kao kontrolirani izlazi. Ispitanici su za RAG startali iz stajaceg uspravnog položaja. Trebali su iskoračiti s odabranom nogom nakon čega bi se prešao IR signal što je aktiviralo brojanje vremena i uključilo jedno od LED svjetala koje se nalazilo u čunju postavljenom ispod sjedalice. Ispitanik je trebao uočiti koji se čunj upalio, šetati do određene sjedalice, sjesti, podići se, vratiti se do startne linije što brže moguće, okrenuti se i ponoviti istu kretnu strukturu. Kada su ispitanici prekinuli IR signal na četvrtom povratku natrag, vrijeme se zaustavilo. Ispitanici nisu znali koji će se od čunjeva upaliti, a izvodila su se tri različita scenarija testiranja (različit redoslijed paljenja čunjeva). CODS testiranje se izvodilo na istom poligonu, ali ispitanici su unaprijed znali koji od čunjeva će se upaliti (Slika 1).



**Figure 1.** Tests of change of direction and speed and reactive agility

**Slika 1.** Testovi brzine promjene smjera kretanja i reaktivne agilnosti

**Statistical analysis**

The normality of the distribution was assessed by the Kolmogorov-Smirnov test. Arithmetic means and standard deviations for all variables were calculated. This paper presents the reliability within the test (based on three repeated measurements). Reliability is evidenced via Cronbach's alpha (CA) and Inter-item coefficient of correlation (IIR) values. Construct validity was determined by assaying the correlations of agility results with body weight and age of the subjects.

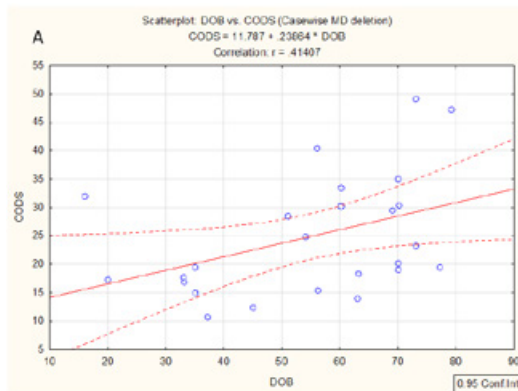
**RESULTS**

*Table 1. Descriptive statistics and reliability measures*

Variables / Varijable	MEAN / AS	SD	Cronbach Alpha	IIR
CODS (s)	24.4	9.7	0.89	0.81
RAG (s)	24.2	10.2	0.88	0.86
Body height / Tjelesna visina (cm)	171.1	11.2		
Body mass / Tjelesna masa (kg)	81.9	13.9		

**Legend:** CODS - change of direction and speed, RAG - reactive agility, MEAN - arithmetic mean, SD - standard deviation, IIR - inter-item coefficient of the correlation

Table 1 represent the results of descriptive statistics and reliability measures. The suggested tests were demonstrated to be highly reliable.



**Figure 2.** Correlation of age of participants and results on tests CODS (1A) and RAG (1B)

Significant age correlations of both CODS and RAG tests were evidenced.

**Statistička analiza**

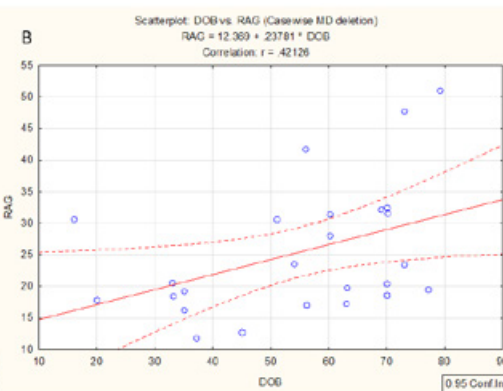
Normalitet distribucije je provjeren Kolmogorov-Smirnovljevim testom. Izračunate su aritmetičke sredine i standardne devijacije za sve varijable. U ovom radu je prikazana pouzdanost unutar testiranja (temeljem tri čestice mjerenja). Pouzdanost je prikazana preko vrijednosti Cronbach alpha (CA) i Inter-item reliability (IIR). Konstruktna valjanost je određena ispitivanjem korelacija rezultata agilnosti s tjelesnom težinom i dobnim ispitanika.

**REZULTATI**

*Tablica 1. Deskriptivna statistika i mjere pouzdanosti*

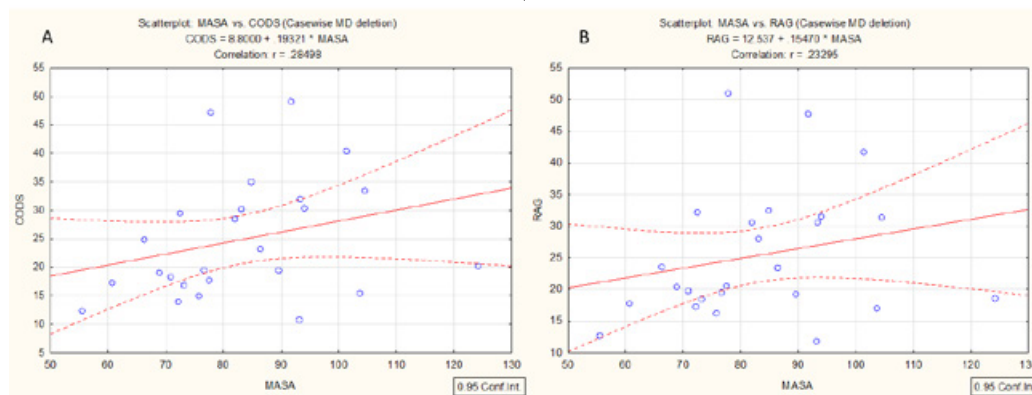
**Legenda:** CODS – brzina promjene smjera kretanja, RAG – reaktivna agilnost, AS – aritmetička sredina, SD – standardna devijacija, IIR – inter-item reliability

U Tablici 1 prikazani su rezultati deskriptivne statistike i mjere pouzdanosti. Testovi su se prikazali visoko pouzdanima.



**Slika 2.** Korelacija dobi ispitanika i rezultata na testovima CODS (1A) i RAG (1B)

Zabilježene su značajne korelacije dobi i CODS i RAG testova.



**Figure 3.** Correlations of body weight and results on CODS (2A) and RAG (2B) tests

Significant correlations of body weight and CODS and RAG tests were evidenced

### DISCUSSION

There are several main findings of this study. First, newly constructed agility tests (RAG and CODS) have been demonstrated to be reliable in patients after knee surgery. Second, the tests evidenced construct validity with respect to the age and body mass of the participants.

The RAG and CODS tests have been demonstrated to be highly reliable. Surprisingly, both tests had similar reliability, which is not consistent with previous research on athletes where higher reliability of CODS was observed compared to RAG. In brief, research in the scope of football-specific agility tests has reported greater reliability of CODS tests compared to RAG (Krolo et al., 2020), the same conclusions were reported in both basketball and futsal players (Sekulic et al., 2019; Sekulic et al., 2017). The explanation most likely is concealing in the specificity of the used test. Specifically, the newly constructed test consisted of walking rather than maximum running as in studies on athletes. In athletes, RAG requires a rapid ability to make decisions, perceptions, observations, and generally developed cognitive capacities, whereas, in tests with a low rate of movement velocity like walking speed, cognitive capacities are unlikely to be as stimulated. Therefore, since cognitive capacities, which basically most differentiate RAG from CODS abilities, were probably not required, respondents had similar results in both newly constructed tests. More specifically, the results of RAG and CODS tests were highly intercorrelated (90% of the common variability), while the results of the RAG and CODS tests in athletes typically evidence an average of 20% of the common variability (Sekulic et al., 2019). Therefore, it is likely to assume that RAG and CODS represent a similar ability in the studied clinical population.

**Slika 3.** Korelacije tjelesne mase i rezultata na testovima CODS (2A) i RAG (2B)

Zabilježene su značajne korelacije tjelesne mase i CODS i RAG testova.

### RASPRAVA

Nekoliko je glavnih nalaza ove studije. Prvo, novo-konstruirani testovi agilnosti (RAG i CODS) su se prikazali pouzdanima kod pacijenata nakon operacije koljena. Drugo, testovi su prikazali konstruktnu valjanost s obzirom na dob i tjelesnu masu ispitanika.

Testovi RAG i CODS su se prikazali kao visoko pouzdani. Neočekivano je što su oba testa imala sličnu pouzdanost, što nije u skladu s prijašnjim istraživanjima na sportašima gdje je zabilježena viša pouzdanost CODS u usporedbi s RAG. Ukratko, istraživanja u području nogomet-specifične agilnosti su zabilježila veću pouzdanost CODS u usporedbi s RAG (Krolo et al., 2020), što je zabilježeno i kod košarkaša i futsal igrača (Sekulic et al., 2019; Sekulic et al., 2017). Objašnjenje najvjerojatnije leži u specifičnosti korištenog testa. Konkretno, novokonstruirani test se sastojao od šetanja, a ne od maksimalnog trčanja kao u istraživanjima na sportašima. Kod sportaša, RAG zahtijeva brzu sposobnost donošenja odluka, percepcije, zapažanja i općenito razvijene kognitivne kapacitete, dok kod testa koji uključuje šetanje vjerojatno kognitivni kapaciteti ne dolaze toliko do izražaja. Stoga, s obzirom da kognitivni kapaciteti, koji u osnovi najviše razlikuju RAG od CODS, vjerojatno nisu bili toliko potrebni, ispitanici su imali slične rezultate kod oba novokonstruirana testa. Detaljnije, rezultati RAG i CODS testova bili su visoko međusobno povezani (90% zajedničkog varijabiliteta), dok rezultati kod RAG i CODS testova kod sportaša uobičajeno prikazuju prosječno 20% zajedničkog varijabiliteta (Sekulic et al., 2019). Stoga, može se pretpostaviti da RAG i CODS predstavljaju sličnu sposobnost kod ispitivane kliničke populacije.

Newly constructed agility tests for the clinical population have been demonstrated to be valid for differentiation by age and body mass. In particular, younger respondents performed better than older participants, while respondents with lower body mass performed better than their participants with higher body mass. These results were expected with regard that numerous studies have evidenced a negative association between age and fitness status (Gladyshev, 2016). The decline of neuromuscular and cognitive capacities that occurs by aging is certainly one of the reasons for this phenomenon (Gladyshev, 2016). Accordant to our results, Japanese research has recorded a deterioration of the agility capacities at the test for respondents older than fifty years of age (Miyamoto et al., 2008). Furthermore, it is established that body composition and body mass affects the motor tasks performance which includes whole-body movements (Nikolaïdis, 2012). A possible explanation seeks in the fact that for respondents with greater body mass is more demanding to move the body in different directions with regard to probably more "ballasts" in total mass (Sillanpää et al., 2009). However, it is requisite for a more detailed analysis of these correlations because the total body mass consists of fat- and lean-body mass, so the final conclusions can not be presented only from these results.

## CONCLUSION

The newly constructed RAG and CODS testing protocols have been demonstrated to be reliable for testing the agility of the untrained clinical population. Therefore, tests can be used to investigate agility with similar subgroups of respondents in future research, but also in clinical practice. The presented tests were valid in the differentiation of groups by age and body mass, which confirms the applicability of tests in this regard. The study findings are of crucial importance for the untrained and clinical population because agility is one of the most important motor abilities directly related to prevention of falls, and injury-prevention. By designing specific tests, it is possible to accurately determine the capacity of agility, which will consequently provide the knowledge necessary for development of appropriate training and rehabilitation programs. Further research on reliability and applicability for various samples of respondents is warranted.

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Novokonstruirani testovi agilnosti za kliničku populaciju su se prikazali valjanima za diferencijaciju po dobi i tjelesnoj težini. Konkretno, mlađi ispitanici su postizali bolje rezultate u odnosu na starije, dok su ispitanici s manjom tjelesnom masom postizali bolje rezultate od težih ispitanika. Ovi rezultati su očekivani s obzirom da su brojna istraživanja zabilježila negativnu povezanost dobi i fitness statusa (Gladyshev, 2016). Razlog se može pronaći u opadanju živčano-mišićnih i kognitivnih sposobnosti sa starenjem (Gladyshev, 2016). U skladu s našim rezultatima, kod Japanskih ispitanika je zabilježeno pogoršanje rezultata kod testa agilnosti nakon pedesete godine života (Miyamoto et al., 2008). Nadalje, poznato je da tjelesna kompozicija i tjelesna masa utječu na izvedbu motoričkih zadataka kod kojih je potrebno pomicati i premještati položaj cijelog tijela (Nikolaïdis, 2012). Moguće objašnjenje leži u činjenici da je težim ispitanicima zahtjevnije brzo pomicati tijelo u različitim smjerovima s obzirom na vjerojatno veći „balast“ (Sillanpää et al., 2009). Međutim, trebalo bi detaljnije analizirati ove poveznice jer se masa tijela sastoji od masne i bezmasne mase pa se ne mogu donositi konačni zaključci iz ovih rezultata.

## ZAKLJUČAK

Novokonstruirani testovi RAG i CODS su se prikazali pouzdanima kod ispitivanja agilnosti netrenirane kliničke populacije. Stoga, testovi se mogu koristiti za ispitivanje agilnosti kod sličnih skupina ispitanika u budućim istraživanjima. Testovi su se prikazali valjanima kod diferenciranja dobnih grupa i grupa po tjelesnoj masi što potvrđuje primjenjivost testova u ovom smislu. Ovakva istraživanja su od ključne važnosti kod netrenirane i kliničke populacije jer je agilnost jedna od važnijih sposobnosti odgovornih za redukciju padova i ozljeda. Kreiranjem specifičnih testova se može precizno odrediti stanje agilnosti pomoću čega se mogu kreirati adekvatni trenažni programi. Buduća istraživanja bi se trebala baviti identifikacijom pouzdanosti i primjenjivosti kod različitih uzoraka ispitanika.

## Zahvala:

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