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Construct Validity Evidence for the Muscle Strengthening Activity Scale (MSAS)

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Abstract **Background**: The 2018 (2nd edition) Physical Activity Guidelines for Americans states that adults should participate in muscle strengthening activity (MSA) of at least moderate intensity using all major muscle groups on two or more days a week. However, these guidelines do not promote specific types of MSA such as muscular strength training or muscular endurance training. This ambiguity, in part, is due to the lack of evidence linking specific types of MSA to health outcomes. And this lack of evidence, in part, is due to the inability to measure varying MSA behavior. This study reports the construct validity evidence for the MSA Scale (MSAS). **Methods**: The following research consists of a second development stage presenting validity evidence for the MSAS. Previous research indicates that seven items can measure three MSA dimensions: a three-item muscular *strength* dimension, a three-item muscular *endurance* dimension, and a single-item *body* weight exercise dimension. The current research used both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to examine the MSAS construct validity. **Results**: EFA indicated a two-factor structure explained 100% of the common variance among the 6 strength and endurance items (3 items per factor with all loadings > .52). The first factor was defined as *strength* and the second *endurance*. CFA indicated the two-factor MSAS measurement model had adequate fit (χ^2/df = 4.24, GFI = 0.97, CFI = 0.92, and RMSEA = 0.09) with *strength* and *endurance* significantly ($p < .001$) predicting all observed variables. Factor *strength* scores were strongly correlated with *strength* sum scale scores and weakly correlated with *endurance* and *body* sum scale scores. Similarly, factor *endurance* scores were strongly correlated with *endurance* sum scale scores and weakly correlated with *strength* and *body* sum scale scores. **Conclusion**: The seven-item MSAS is a simple and valid tool for measuring MSA behavior in adults. Two additional items are included in the MSAS to quantify MSA participation.

Keywords: *Muscle strengthening activity (MSA), Construct validity, Exploratory factor analysis (EFA), Confirmatory factor analysis (CFA)*

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1. Introduction

The 2018 Physical Activity Guidelines for Americans (2nd edition) reinforces its previous recommendation for the promotion of muscle strengthening activity (MSA) of at least moderate intensity using all major muscle groups on two or more days a week by all adults [1]. For many Americans, however, this recommendation remains vague. For example, guidelines specifically state that no specific amount of muscle strengthening time is recommended [2]. Additionally, no clear program design variables are given in terms of MSA benefits (i.e., muscular strength or muscular endurance). The likely reason for this ambiguity is the lack of evidence linking the various types of MSA to health outcomes. Furthermore, it is also likely that evidence associating specific types of MSA with health outcomes is sparse because there is no valid assessment tool available to measure the different types of MSA behavior. The purpose of this study was to fill this aforementioned gap in the MSA literature. Specifically, this research examined the construct validity of a newly developed assessment tool to measure MSA behavior, the Muscle Strengthening Activity Scale (MSAS).

2. Materials & Methods

2.1. Study and Scale Development Procedures

The development procedures related to the MSAS have been explained in detail elsewhere [3]. Briefly, A total of N=1,240 adults agreed to take the MSAS using an electronic survey tool. Of which, N=400 adults indicated participating in regular MSA. After a first-stage reliability and item analysis, the pilot version of the MSAS resulted in a seven-item scale measuring three distinct MSA dimensions: a three-item muscular *strength* dimension, a three-item muscular *endurance* dimension, and a single-item *body* weight exercise dimension. The final format of the MSAS resulted as follows. A screener question is included at the top of the instrument to ask individuals if they regularly participate in MSA. Those responding “No” are instructed not to continue to the rest of the instrument. Part I of the MSAS contains the seven scale items, each with the same five-category rating rule ranging from “Never true” to “Always true”. Item stems consist of personalized statements regarding muscular strength training behavior, muscular endurance training behavior, and body weight exercise training behavior. For example, “I often exercise my muscles with heavy weight that I can lift 1 to 8 times”. Part II of the MSAS contains two items asking participants about their frequency and duration of MSA *participation*. These part II items are included to quantify amounts of MSA performed, however, these items are not evaluated in this study. At the bottom of the MSAS, directions are given to obtain *strength*, *endurance*, and *body* attribute scores as well as an MSA *participation* score.

2.2. Statistical Analyses

The statistical analysis plan for the current study followed five steps [4]. First, inter-item correlation coefficients were computed. Inter-item correlation coefficients are bivariate correlation coefficients between each pair of MSAS items with a suggested strength cutoff of $r > .30$. This step also included testing the adequacy of the correlation matrix for factor analysis. Second, exploratory factor analysis (EFA) was performed as a subjective means of construct validity evidence. EFA uses common variance among the items to extract a parsimonious set of factors. Initially, all seven items were included in the EFA, however, since the *body* item showed a weak loading to the *endurance* factor, it was removed from the analysis. EFA extraction method was by maximum likelihood (ML) and factors were rotated using an orthogonal varimax technique. Third, convergent and divergent validity evidence was obtained by examining correlations between EFA scores and MSAS dimension sum scores. Fourth, confirmatory factor analysis (CFA) was performed as an objective test of the hypothesized six-item two-factor MSAS measurement model. Model fit was assessed using the following statistics and criteria: comparative fit index (CFI > 0.90), root mean square error of approximation (RMSEA < 0.10), goodness of fit index (GFI > 0.90), adjusted goodness of fit index (AGFI > 0.90), Tucker-Lewis index (TLI > 0.90), normed fit index (NFI > 0.90), and Akaike’s information criterion (AIC, relatively lower values indicate better fit). As well, the chi-square statistic (χ^2) to degrees of freedom (df) ratio (i.e., normed chi-square) was used with acceptable criteria of less than 5.0 [5,6,7]. Fifth and lastly, the analysis of convergent and divergent validity was again obtained by examining correlations between CFA scores and MSAS dimension sum scores. All correlations were Pearson coefficients from the SAS CORR procedure and Python Numpy package. EFA was conducted using the SAS FACTOR procedure and Python factor_analyzer package. Finally, CFA was conducted using the SAS CALIS procedure and Python factor_analyzer package. SAS version 9.4 and Python version 3.7 were used to analyze all data in duplicate, to ensure consistency [8,9,10,11].

3. Results

Table 1 contains bivariate Pearson correlation coefficients for the six items associated with the muscular endurance and muscular strength MSAS subscales. As expected, the largest correlations are between items within each theorized MSAS subscale. The only correlation coefficient not meeting the recommended convergent validity criteria ($r > .30$) is the correlation between items 2 and 3 of the strength subscale ($r = .268$), albeit very close and significant ($p < .05$). Additionally, Bartlett’s test of sphericity, testing the null hypothesis that the observed correlation matrix is equal to the identity matrix, was large and significant, $\chi^2 = 343.2$, $p < .001$. As well, Kaiser's measure of sampling adequacy (MSA), assessing the factorability of the observed variables, was acceptable, *MSA* = .664.

Table 2 contains results from the EFA with varimax rotated factor pattern for the MSAS. Results indicated a two-factor structure explained 100% of the common variance among the 6 strength and endurance items. The factor structure was simple with three items strongly loading (loadings > .52) to each factor and weak cross-loadings (loadings < .31). The first factor was defined as *strength* and the second as *endurance*, as expected, and hereafter referred to as such. Table 3 contains bivariate correlation coefficients between the three dimension MSAS sum scores and the two EFA factor scores. EFA *strength* scores (EFA2) were strongly correlated with *strength* ($r = .983$, $p < .05$) sum scale scores and weakly correlated with *endurance* ($r = .098$, $p = .051$) and *body* ($r = -.187$, $p < .05$) sum scale scores. Similarly, EFA *endurance* scores (EFA1) were strongly correlated with *endurance* ($r = .985$, $p < .05$) sum scale scores and weakly correlated with *strength* ($r = .164$, $p < .05$) and *body* ($r = .293$, $p < .05$) sum scale scores.

Table 1. Correlation matrix of the two MSAS subscale items (N=400)

Items	Q1	Q2	Q3	Q4	Q5	Q6
Q1: Strength	1					
Q2: Strength	**.396**	1				
Q3: Strength	**.408**	**.268**	1			
Q4: Endurance	.046	.013	**.189**	1		
Q5: Endurance	**.129**	.056	**.246**	**.419**	1	
Q6: Endurance	.064	-.054	**.246**	**.302**	**.382**	1

Note. Bivariate Pearson correlations. Bold values are significant (ps < .05). Bartlett test of sphericity: $\chi^2 = 343.2$, $p < .001$. Kaiser's Measure of Sampling Adequacy (MSA): MSA = .664.

Table 2. Exploratory factor analysis (EFA) rotated factor pattern for the two MSAS subscales (N=400).

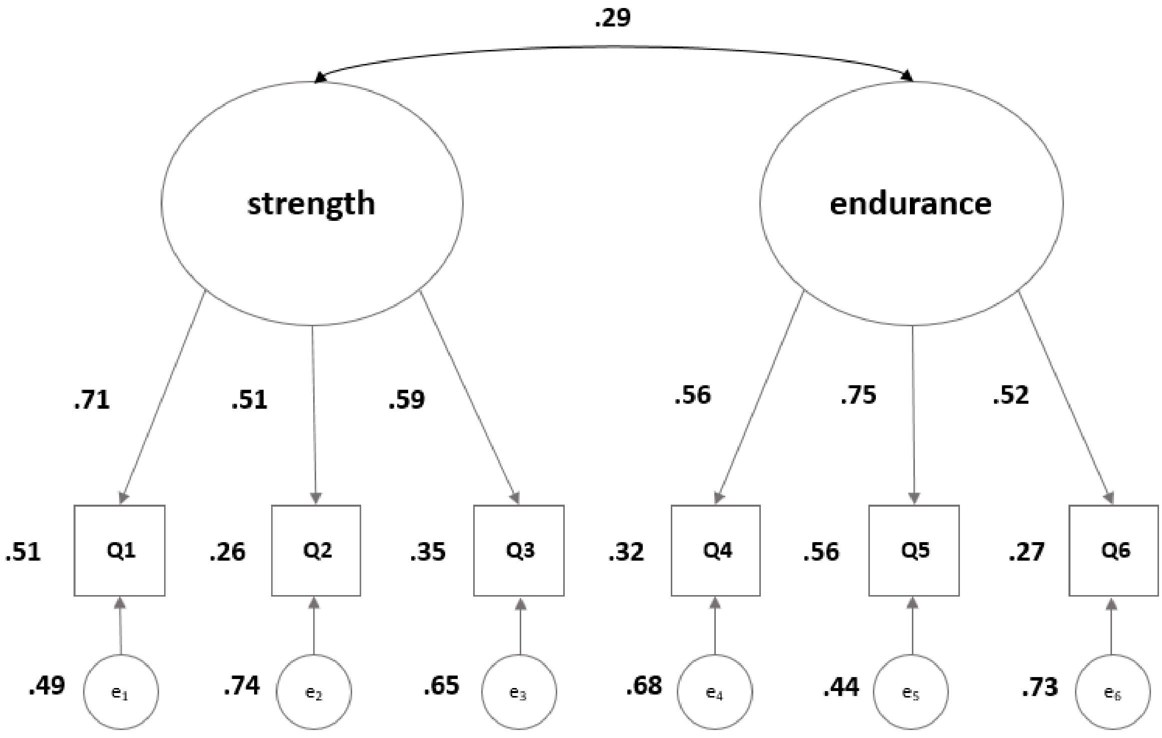
Item	Factor1	Factor2	h^2
Q1: Strength	.	.748	.563
Q2: Strength	.	.535	.287
Q3: Strength	.	.520	.368
Q4: Endurance	.582	.	.339
Q5: Endurance	.682	.	.478
Q6: Endurance	.560	.	.315
Eigenvalue	2.617	1.543	4.160
% explained	62.9	37.1	100.0

Note. Loadings less than 0.4 are not printed. Total explained common variance by two factors is 100%. h^2 is communality. Extraction method by maximum likelihood (ML). χ^2 test with H_0: 2 factors are sufficient, p = .115. Last two eigenvalues were negative. Eigenvalues in this table are from the rotated solution and therefore represent the sum of the squared loadings.

Table 3. Correlations between the two EFA factor scores and the three MSAS sum scores (N=400)

Variable	Strength	Endurance	Body	EFA1	EFA2
Strength	1				
Endurance	**.170**	1			
Body	**-.144**	**.269**	1		
EFA1	**.164**	**.985**	**.293**	1	
EFA2	**.983**	.098	**-.187**	.087	1

Note. Bolded Pearson correlations are significant (*ps* < .05). EFA1 is the endurance factor. EFA2 is the strength factor. Underlined correlations are of primary interest.



Note. Model degrees of freedom (*df*) = 21 (moments) – 13 (parameters) = 8. All standardized weights and coefficients are significant (*ps* < .05). χ^2 for 1 factor model = 138.8, *df*=9. χ^2 for 2 factor model = 33.9, *df*=8. χ^2 for difference = 104.9, *df*=1, *p* < .001.

Figure 1. Confirmatory factor analysis (CFA) of the two-factor MSAS measurement model

Figure 1 displays the MSAS measurement model, depicting two latent factors (three items each), as indicated by the EFA. A two-factor measurement model showed to be needed over a single-factor model (χ^2 for difference = 104.9, *df*=1, *p* < .001). Additionally, all items were significantly (*p* < .001) predicted by the *strength* and *endurance* factors with positive loadings indicating their direct relationship. Table 4 contains fit statistics for the two-factor MSAS measurement model and indicates adequate fit (χ^2/df = 4.24, *GFI* = 0.97, *CFI* = 0.92, and *RMSEA* = 0.09). Table 5 contains correlations between the three dimension MSAS sum scores and the two CFA factor scores. CFA *strength* scores (CFA2) were strongly correlated with *strength* (*r* = .985, *p* < .05) sum scale scores and weakly correlated with *endurance* (*r* = .278, *p* < .05) and *body* (*r* = -.114, *p* < .05) sum scale scores. Similarly, CFA *endurance* scores (CFA1) were strongly correlated with *endurance* (*r* = .972, *p* < .05) sum scale scores and weakly correlated with *strength* (*r* = .274, *p* < .05) and *body* (*r* = .236, *p* < .05) sum scale scores.

Table 4. CFA results for the MSAS measurement model

Statistic	Value	Criteria
χ^2/df	4.240	< 5.00
CFI	0.922	> 0.90
RMSEA	0.090	< 0.10
GFI	0.972	> 0.90
AGFI	0.926	> 0.90
TLI	0.853	> 0.90
NFI	0.902	> 0.80
AIC	59.92	*

Note. χ^2/df is chi-square divided by degrees of freedom. CFI is comparative fit index. RMSEA is root mean square error of approximation. GFI is goodness of fit index. AGFI is adjusted goodness of fit index. TLI is Tucker-Lewis index. NFI is normed fit index. AIC is Akaike's information criterion. *a relatively smaller AIC indicates a better fit.

Table 5. Correlations between the two CFA factor scores and the three MSAS scores (N=400)

Variable	Strength	Endurance	Body	CFA1	CFA2
Strength	1				
Endurance	**.170**	1			
Body	**-.144**	**.269**	1		
CFA1	**<u>.274</u>**	**<u>.972</u>**	**<u>.236</u>**	1	
CFA2	**<u>.985</u>**	**<u>.278</u>**	**<u>-.114</u>**	**.380**	1

Note. Bolded Pearson correlations are significant (*p*s < .05). CFA1 is the endurance factor. CFA2 is the strength factor. Underlined correlations are of primary interest.

4. Discussion

The ultimate question under study here is, does the MSAS have acceptable measurement properties? Results from this study suggest the answer is 'yes'. Using both subjective and objective statistical approaches, this study has shown that the MSAS measures three distinct traits. Furthermore, this study has shown that the three simple sum scores from the MSAS provide the same measurement properties. Given these statistical results, it can be determined that the three distinct latent traits found in this study are indeed the same traits they were developed to measure. That is, a three-item muscular *strength* trait, a three-item muscular *endurance* trait, and a single-item *body* weight exercise trait.

Previous research on the MSAS has also provided positive psychometric evidence [3]. That is, the MSAS was developed using a multi-stage content validity procedure where a large pool of items were built using content experts and a focus group and subsequently reduced and modified using a series of pilot tests and item analyses. Furthermore, this previous research showed that MSAS subscale (*strength* and *endurance*) items were reliable (internally consistent) with the *body* weight item resolved to measure its own single-item trait. Item category scales (five-category rating rule ranging from "Never true" to "Always true") were also modified and showed to finally function well in this previous research.

Therefore, the present totality of evidence concerning the MSAS clearly supports its validity and reliability in measuring three MSA behaviors: muscular *strength*, muscular *endurance*, and *body* weight exercise. Future studies are still warranted, however. One recommendation is to study the extent to which the MSAS holds up to the critical power of modern psychometric examination (i.e., item-response theory (IRT)). A second recommendation is to further evaluate MSAS construct validity by examining its ability to separate MSA participants with known differences in MSA behavior (e.g., power lifters vs. circuit trainers vs. yogis). A third recommendation is to study the extent to which the MSAS can detect changes in MSA behavior (i.e., specificity), be it via intervention or personal willpower. A final recommendation is to evaluate part II of the MSAS for its ability to validly quantify participation in MSA.

5. Conclusions

The seven-item MSAS is a simple and valid tool for measuring specific MSA behavior in adults. Two additional items are included in the MSAS to quantify MSA participation, but to date, have not been validated. Caution should be taken for item missing values, since this research used item summation for trait scores. The MSAS is free to use without restrictions, providing proper citation.

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Appendix: (download from: http://www.fitmetrics.org/MSAS.pdf)

Muscle Strengthening Activity Scale (MSAS)

Please circle your best response to each statement.

Do you regularly engage in muscle strengthening activity (such as push-ups, sit-ups, yoga or weight lifting) as a form of exercise?

Yes (continue to the rest of the survey)
No (you can stop here, thank you)

Think about your muscle strengthening exercise in a **typical week** when responding to each statement.

Muscle Strengthening Activity Scale (MSAS) Part I	Never True	Rarely True	Sometimes True	Usually True	Always True
1. I often exercise my muscles with heavy weight that I can lift 1 to 8 times.	1	2	3	4	5
2. I make sure to rest for long periods of time between muscle strengthening sets in order to lift heavy weight.	1	2	3	4	5
3. I make an effort to strengthen all major muscles of my body.	1	2	3	4	5
4. I often arrange several exercises in an order and quickly move from one exercise to the next.	1	2	3	4	5
5. I spend a lot of effort performing floor exercises for my stomach (like sit-ups, crunches, leg raises) lasting until I fatigue.	1	2	3	4	5
6. I often rest for short periods between muscle strengthening sets to build endurance.	1	2	3	4	5
7. I often exercise my muscles using only my body weight (like calisthenics, yoga, Pilates).	1	2	3	4	5

Muscle Strengthening Activity Scale (MSAS) Part II							
1. On average, how many **days per week** do you exercise your muscles?	1	2	3	4	5	6	7
2. On a typical day, how many **minutes** do you approximately spend exercising your muscles?	10	20	30	45	60	90	120+

Scoring Instructions

Part I: Add questions 1, 2 and 3 to get a ***Strength*** score. Add questions 4, 5 and 6 to get an ***Endurance*** score. Question 7 is a ***Body*** exercise score.
Part II: Multiply questions 1 and 2 to get a MSA ***Participation*** score. Minimum score is 10 minutes per week and maximum score is 840 minutes per week.