Validity of the Titmus Vision Screener: A Comparison with the Snellen Chart

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Abstract

Given limited knowledge regarding validity of the Titmus vision screener, we sought to compare visual acuity measurements obtained from the Titmus with that from the Snellen chart and assess the validity properties of the Titmus as a screening instrument to detect vision impairment. Visual acuity was measured in 150 participants recruited from an academic ophthalmology practice, using the Snellen chart as well as the Titmus vision screener. Visual acuities from the Titmus and Snellen were compared and validity of the Titmus vision screener was assessed by computing sensitivity and specificity. Using Snellen visual acuity as the reference standard, the sensitivity of the Titmus vision screener to detect vision impairment, defined as visual acuity worse than 20/40, was 92% [95% CI (72.5, 98.6)] and the specificity was 64% [95% CI (57.9, 70.1)]. Comparisons of the precise visual acuity level revealed poor agreement between the two methods [weighted Kappa: 0.15, 95% CI (0.08, 0.21)]. Visual acuities obtained from the Titmus were, on average, two lines worse than Snellen visual acuities. [(logMAR Snellen − logMAR Titmus) = - 0.19 ± 0.29, 95% confidence interval (CI) (-0.23, -0.16)]. Titmus vision screener is a sensitive tool to detect visual impairment. However high false positive results and poor agreement with Snellen limits its widespread use in clinical applications.

Introduction

Vision impairment (VI) affects 191 million people globally, mostly due to treatable or preventable causes [1]. VI is associated with a wide range of adverse outcomes including poor quality of life, worse functioning and detrimental impact on mental health [2, 3, 4, 5, 6]. Vision screening is an important public health measure to address the burden of VI. In addition to identifying correctable refractive error, vision screening is the first step in diagnosing more serious conditions, such as cataract, age-related macular degeneration, diabetic retinopathy and glaucoma, which are often asymptomatic in early stages and can benefit from treatment.

There are numerous charts and methods used for visual acuity (VA) testing. The most commonly performed VA test in the eye care setting is the Snellen test, which requires a well-lit Snellen chart situated 20 feet (6 meters) or equivalent from the patient. Vision screening is also routinely performed in other settings including primary care clinics, occupational health screening, school health clinics, and vision testing for driver licensing. Space and lighting requirements for testing vision are factors limiting the use of conventional vision testing methods in non-eye care settings. The Titmus vision screener is an instrument that is widely used in these situations, given its portability and ease of use [6, 7]. It is a vision screening device with optically simulated distance and near vision settings and has built -in lighting for   vision testing.

Despite the design advantages and frequent use of the Titmus vision screener, there is a lack of detailed knowledge of its validity properties and comparability with conventional VA test results. A study by McAlister et al that compared VA from Snellen to that of the Titmus, among a cohort of young healthy subjects (mean age: 22.9 years, range: 20-29 years) concluded that the Titmus VA did not differ significantly from Snellen VA [8]. However, this study did not examine the concordance of the two tests or characterize the validity profile of the Titmus vision screener. Validation characteristics are critical to establish and confirm the utility of Titmus as a screening tool for detecting VI. Thus, the goal of this study was to assess the concordance of Titmus VA in comparison to Snellen VA and evaluate the validity of VA assessment using the Titmus vision screener.

Materials and Methods

Participants

150 participants (93 female and 57 male participants), age 18 years or older were enrolled from eye care clinics at the Kellogg Eye Center, University of Michigan, between August 2013 and July 2014. Patients who had an intraocular surgery in the past 6 months were ineligible for the study. This study was approved by the University of Michigan Institutional Review Board and adhered to principles of the Declaration of Helsinki. Informed consent was obtained from all participants. The following nominal variables for ocular diagnoses were characterized based on clinical diagnoses provided by the eye care provider: cataract (yes, no, or indeterminate), intraocular lens (yes, no, or indeterminate), glaucoma (yes, no, or indeterminate), and age-related macular degeneration (yes, no, or indeterminate).

VA Testing

VA measurements were obtained using the Snellen and the Titmus tests by trained staff members on the same day of the participant's scheduled clinic examination. The order of testing was not randomized and was performed in such a way to minimize disruption to the participant's clinic visit. 72% had Titmus testing first followed by Snellen testing, 18% had the opposite order, and the order was indeterminate in 10%. Right eye was tested first followed by left eye. Participants used their glasses or contact lenses during the VA assessment if they had refractive correction. None of the participants were intentionally tested under cycloplegia to control for proximal accommodation. Thus, VA compared using the two methods was the participant's presenting VA.

Snellen Testing

VA was tested using a Snellen chart displayed by means of a projection system (M&S Technologies Inc., Skokie, Illinois). Optotypes projected on the chart were letters. Participants were seated in a standard clinical examination lane and were instructed to wear their refractive correction, if they had any. VA was tested in one eye at a time by blocking the non-tested eye using a

hand-held occluder. As per the standard of clinical care, participants were asked to identify letters, starting with larger sizes and then progressing to smaller sizes on the projection screen. The test ended when a majority (more than 50%) of letters on a line could not be read correctly by the participant. VA corresponded to the line on which majority of the smallest letters were correctly identified. VA was recorded as a fraction, with numerator representing the distance in feet at which the participant identified the smallest letter and denominator representing the distance at which a person with normal vision would be expected to identify the same letter.

Titmus Testing

The occupational model of the Titmus 2a vison screener (Titmus Optical Inc., Chester, Virginia) was used in this study. The instrument was set to distance vision setting. Participants were asked to wear their refractive correction, if any. The test was conducted in a seated position with the participant's forehead placed on the forehead rest and eyes positioned to look through the eyepiece of the instrument. Each eye was tested separately by pressing the occluder pad on the remote to occlude the eye piece of the non-tested eye. VA was measured by presenting a self-lit slide. Each slide contained a group of diamond shaped figures. The diamond shaped figures contained four rings, three of which had a break in the oblique axis and one of which was unbroken. Participants were asked to name the position of the unbroken ring. The test began by the participant identifying the most easily identifiable ring and ended when two consecutive answers were incorrect. VA was recorded as a fraction, known as the Snellen equivalent, with the numerator representing the distance in feet at which the participant identified the smallest shape and the denominator representing the distance at which a person with normal vision would be expected to identify the same shape.

Statistical Analysis

The sample size was estimated based on a desired level of precision for estimates of accuracy. Based on the binomial distribution, a sample size of 150 participants will provide a 95% CI half-width around a sensitivity or specificity estimate of 90% that will be ≤0.06 (i.e., 90% ± 6%) with a probability of 0.996.

The statistical analyses were based on individual eyes (n = 300 eyes). Titmus VA had the following categories: 20/13, 20/17, 20/18, 20/20, 20/22, 20/25, 20/30, 20/35, 20/40, 20/50, 20/70 and 20/100. Snellen VA categories were as follows 20/15, 20/20, 20/25, 20/30, 20/40, 20/50, 20/60, 20/70, 20/80, 20/100, 20/200 or worse. For the VA categories that were mis-aligned between Titmus and Snellen, re-categorization was done to facilitate assessment of degree of agreement. For example, for a VA 20/20 or better, the Titmus test had 20/13, 20/15, 20/17, 20/18 and 20/20 VA categories, while the Snellen test had 20/15 and 20/20 categories. To assist direct comparison and assessment of agreement, the 20/13 Titmus category was re-categorized as 20/15. Likewise, 20/17 and 20/18 VA findings from the Titmus test were re-categorized to the 20/20 category. Similar re-categorization procedures were carried out for misalignments of VA values worse than 20/20 as well. This resulted in the following final common VA categories: 20/15, 20/20, 20/25, 20/30, 20/40, 20/50, 20/70, 20/100, and 20/200. The re-categorized data were used for calculation of the Kappa statistic only. All other statistical analyses were based on the original Titmus and Snellen categories. The weighted Kappa statistic was computed using Cicchetti-Allison kappa coefficient weights [9].

Sensitivity and specificity were computed based on VI being defined as VA worse than 20/40, which corresponds to the Center for Disease Control's definition of VI and the State of Michigan's 20/40 or better requirement to obtain an unrestricted driver's license [10,11]. In addition, sensitivity and specificity were also calculated by moving the threshold for VI using the Titmus VA from 20/40 to 20/50 and 20/70.

For computing the averages and comparing Snellen and Titmus VAs, all VA values were converted to logMAR equivalent [12]. Mean difference in VA between Snellen and Titmus was computed and a paired t-test was performed to test for significant difference in VA between the two methods. Plots were constructed using the Bland-Altman method to visualize the degree of agreement between the two methods of VA assessment [13,14].

To further assess the factors that influenced the mean VA difference between the Titmus and Snellen

tests, linear mixed regression modeling was performed to analyze the effect of age, gender, race, use of glasses/contact lens correction, order of testing, presence of refractive error, cataract, age-related macular degeneration, and glaucoma. This model accounted for the correlation between eyes of a subject. Statistical analyses were performed using SAS 9.3 (SAS Institute, Cary, North Carolina).

Results

There were 150 study participants whose ages ranged from 18 to 89 years. Characteristics of the study population are summarized in Table 1. The mean ± standard deviation of Snellen logMAR VA was 0.15 ± 0.27 and that of Titmus logMAR VA was 0.31 ± 0.33. The distribution of differences between the Titmus logMAR VA and the Snellen logMAR VA is presented in Figure 1.

VAs obtained from Titmus and Snellen were significantly different (paired t-test P <0.0001). On average the Titmus screener yielded VA measures that were two lines worse than VA measures using the Snellen chart [mean difference (logMAR Snellen –logMAR Titmus) = - 0.19 ± 0.29, 95% CI (-0.23, -0.16)]. Linear mixed regression modeling found no significant associations of age, race, gender, order of testing, use of glasses or contact lens, presence of refractive errors, cataract, age-related macular

degeneration or glaucoma with the difference between the Titmus and Snellen VA measures.

The agreement between the two measures, Titmus and Snellen was 'slight', after re-categorizing the visual acuities so that VA categories of the two tests were uniform [weighted Kappa: 0.15, 95% CI (0.08, 0.21)]. A Bland-Altman plot representing the comparison of Titmus and Snellen VA is presented in Figure 2.

The Bland-Altman plot shows that the difference in VA between Snellen and Titmus tests falls within the limits of agreement for VAs better than 20/20 (logMAR VA = 0) and worse than 20/100 (logMAR VA = 0.7), while more variability between measurements is observed for VAs between 20/20 and 20/100.

The Titmus test had a sensitivity of 92.0% [95% CI (72.5, 98.6)] to detect VI (VA worse than 20/40) and specificity of 64.3% [95% CI (58.0, 70.1)]. The negative predictive value was 98.8% and the positive predictive value was 20.4%. Upon moving the VI threshold to 20/50 and 20/70, as suggested by our result of about a two-line difference in VA between the Titmus and the Snellen, there was an improvement in specificity and in kappa statistic, but at the cost of reduced sensitivity. The results at various thresholds are presented in Table 2.

The sensitivity and specificity of Titmus vision screener stratified by age, gender, race, and the most

Table 1. Characteristics of the study population (N=150 study participants).	
Variable	
Age (years) Mean (SD)	53.3 (16.9)
Sex N (%)	
Female	93 (62.0%)
Male	57 (38.0%)
Race N (%)	
White	116 (77.3%)
Black	16 (10.7%)
Others	13 (8.7%)
Indeterminate	5 (3.3%)
Eye Conditions N (%)	
Cataract	50 (33.8%)
Intraocular Lens	28 (18.9%)
Glaucoma	23 (15.5%)
Age-related Macular Degeneration	6 (4.1%)

Table 2. Sensitivity and specificity to detect vision impairment using the Titmus vision screener at various thresholds.

Titmus Vs Snellen	Sensitivity (95% CI)	Specificity (95% CI)	Kappa
20/40 (6/12) Threshold[1]	0.92 (0.73, 0.97)	0.64 (0.58, 0.70)	0.22 *
20/50 (6/15) Threshold[2]	0.80 (0.59, 0.92)	0.78 (0.72, 0.83)	0.30 *
20/70 (6/21) Threshold[3]	0.64 (0.43, 0.81)	0.87 (0.82, 0.91)	0.36 *

1: Snellen visual acuity worse than 20/40 vs Titmus visual acuity worse than 20/40

2: Snellen visual acuity worse than 20/40 vs Titmus visual acuity worse than 20/50

3: Snellen visual acuity worse than 20/40 vs Titmus visual acuity worse than 20/70

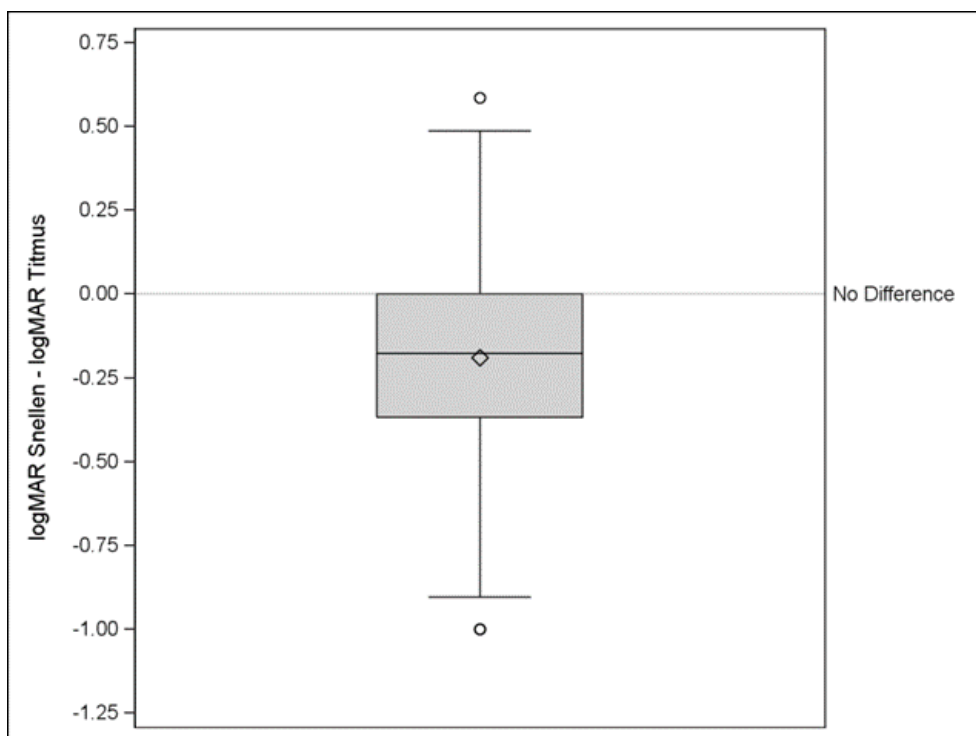*Kappa significantly different from 0, p-value < 0.05

Figure 1. Distribution of difference between logarithm of minimum angle of resolution (logMAR) Snellen and logMAR Titmus.

Diamond in the box represents the mean.

Center line in the box represents the median.

Shaded box represents the interquartile range.

Circles represent the outliers.

Whiskers, upper and lower, represent the distance between the maximum observation and upper quartile, minimum observation and lower quartile respectively.
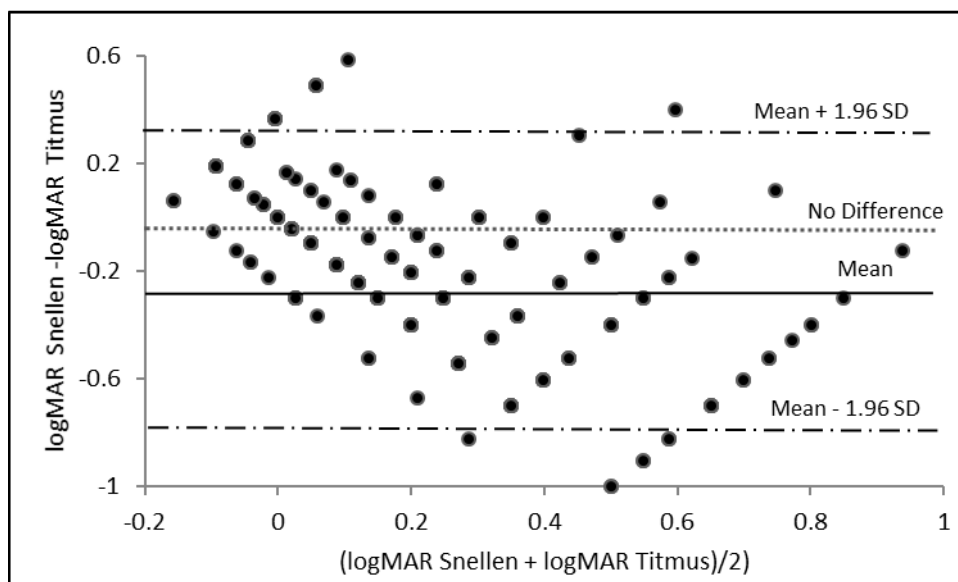
Figure 2. Bland-Altman plot showing the relationship between the Titmus and Snellen Visual Acuity.

Solid black line represents the mean difference between the logarithm of minimum angle of resolution (logMAR) visual acuity of Titmus and Snellen tests.

Dashed lines represent the upper and lower limits of agreement.

Dotted line represents no difference between the two methods.

common ocular condition of cataract is summarized in Table 3.

Discussion

This study demonstrates that the Titmus vision screener is a valuable screening tool for detecting VI (VA worse than 20/40) in a diverse sample population. The utility of the Titmus as a vision screening instrument is evidenced by its high sensitivity (92.0%) and negative predictive value (98.8%). However, the specificity level of 64.3% and positive predictive value of 20.4% indicates that numerous false positives would require further evaluation. In the context of vision screening, false positive vision screening would prompt a referral for a comprehensive eye examination, which is noninvasive and relatively risk free. Thus, at a 20/40 (6/12) threshold, the Titmus test correctly identifies nearly all of those with VI but overestimates the number of people with VI, thereby imposing added costs of time and health care expenses associated with the follow-up comprehensive eye examination. Titmus has a limited role as a clinical diagnostic tool given its specificity, which yields numerous false positives. Given the validity profile of Titmus vision screener, it is an appropriate device to use as a screening tool to detect VI [15].

In terms of comparison of VA categories, the Titmus test did not yield results that closely matched the Snellen VA, as illustrated by a weighted kappa statistic of 0.15, indicative of slight agreement. The Titmus VA was, on average, two lines worse than the Snellen VA. Hence the Titmus test is not an accurate means to measure VA in eye care settings. As expected, upon moving the VI criteria one or two lines worse in the Titmus test, there was a gain in specificity at the cost of lower sensitivity levels. At a 20/50 threshold, the specificity is 78% without excessive loss of sensitivity. The degree of agreement as indicated by the kappa statistic improved when the Titmus VI thresholds were one or two lines worse than the 20/40 cut-off. This information would be of use when making referrals for VI based on the Titmus vision screener.

Studies evaluating the validity of the Titmus vision screener are very limited. Contrary to results of this study, a previous study, which also compared Titmus VA to Snellen VA, found that Titmus VA was not significantly different from Snellen VA [8]. The sample size in that study was smaller (n = 59) and consisted of

Table 3. Sensitivity[#] and specificity[#] of Titmus vision screener stratified by age, gender, race, and the most common ocular condition of cataract.

Variable (n)	Sensitivity (95%CI)	Specificity (95%CI)	Kappa
Age			
< 40 years (n=43 eyes)	1 (0.29, 1.00)	0.80 (0.64, 0.91)	0.36 *
40-65 years (n=137 eyes)	0.90 (0.56, 0.99)	0.68 (0.59, 0.76)	0.20*
>65 years (n=97 eyes)	0.92 (0.62, 0.99)	0.52 (0.41, 0.63)	0.18 *
Sex			
Male (n=110 eyes)	1 (0.75, 1.00)	0.60 (0.49, 0.70)	0.26 *
Female (n=167 eyes)	0.83 (0.52, 0.98)	0.67 (0.59, 0.74)	0.18 *
Race			
Black (n=26 eyes)	1 (0.54,1.00)	0.80 (0.56,0.94)	0.65 *
White (n=215 eyes)	0.93 (0.66, 0.99)	0.64 (0.57, 0.70)	0.17 *
Lens Status			
Cataract (n=94 eyes)	0.87 (0.47, 0.99)	0.65 (0.54, 0.75)	0.20 *
No Cataract (n=177 eyes)	1 (0.78,1.00)	0.63 (0.55, 0.74)	0.22 *

The cut-point used for calculating sensitivity and specificity was a Snaellen VA worse than 20/40 versus a Titmus VA worse than 20/40.

*Kappa significantly different from 0, p-value < 0.05

much younger participants (20-29 years old). It is possible that the younger age and lack of ocular conditions like cataract, glaucoma or retinopathies, along with the resultant homogenous and mostly very good VAs influenced the results of the previous study. When we considered only those participants younger than 40, we did find that VA values obtained from the two methods had better agreement (kappa = 0.36), although within this subset, the VA obtained from the two methods remained significantly different (Paired t-test P = 0.013).

Variation in the VA test results from Titmus and Snellen testing could be due to various factors. Firstly, optotypes used in the two tests differ. Titmus optotypes include a series of broken and unbroken rings, whereas the Snellen optotypes are letters. Difference in optotypes is an important factor leading to varied test results. Previous studies have reported that visual

resolution of letters is better than that of Landolt C testing [16,17], which corresponds to the results of this study. Secondly, participant positioning and head posture in the Titmus and Snellen testing were different. The Titmus testing procedure required the participants to look into the eye piece of the instrument, while the Snellen test was performed with the participants looking straight ahead at a wall mounted screen. This leads to considerable variation in posture, potentially leading to discrepant test results.

As reported by several studies, VA assessment by two different methods often leads to varied results, and the results of this study are consistent with this observation [18,19, 20, 21, 22]. Hence there is a need for exercising caution when comparing the VA values obtained by two methods. While the purpose of conducting a VA test (e.g., screening versus in-clinic testing versus research) should be considered in

deciding upon the VA test to be used, standardizing not only the charts used to measure VA but also the testing protocol and VA reporting is necessary to obtain reliable and comparable results [23, 24].

This study did not compare Titmus test with the 'gold standard' of VA testing which involves testing under a carefully standardized protocol with use of the Early Treatment Diabetic Retinopathy Study (ETDRS) chart [25]. However measurement of Snellen VA is the clinical care standard for measuring VA, both in eye care and non-eye care settings, and thus comparison of Titmus VA to Snellen VA has more practical implications. Future studies comparing VA measures obtained using the Titmus and ETDRS are warranted, to fill the gap in knowledge regarding validity of different VA assessment techniques. Lack of quantitative measurement of illumination used in the two testing methods is another limitation of this study, although the Titmus test made use of the device's built-in illumination and the Snellen test employed standard lighting used in the clinic setting.

Conclusion

The Titmus vision screener is a device that is sensitive to detect VI. Use of Titmus rather than Snellen to assess VA in clinical practice is not supported by our findings, due to poor agreement between the two methods. Given the magnitude of VI as a public health concern and validity profile of the Titmus test, its current use as a screening instrument is appropriate.

Acknowledgment

Conflict of Interest

The authors declare that they have no conflict of interest.

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