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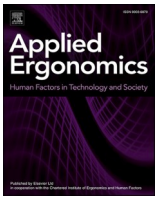

Examining the impact of grip strength and officer gender on shooting performance

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ABSTRACT

Background: Effective shooting performance relies heavily on sufficient grip strength. However, some standard issue pistols used by police services may have a trigger weight that causes problems for officers with insufficient grip strength, including female officers. The current study aimed to replicate previous findings, which show that grip strength is positively related to shooting performance. We also sought to determine what grip strength is required to achieve proficient scores on a standard police pistol qualification (PPQ) when a heavy trigger weight (i.e., 8lbs–12lbs) is used. Finally, we explored the relationship between officer gender and PPQ scores to determine if grip strength plays a mediating role in this relationship.

Method: The dominant hand grip strength (in lbs) of 86 male and 32 female officers were recorded prior to their participation in their agency mandated annual PPQ. Officer gender, grip strength, and PPQ scores were analyzed to explore how they related to one another.

Results: Grip strength significantly impacted officers' ability to pass the PPQ, with female officers possessing lower grip strength compared to male officers, as well as achieving poorer scores on the PPQ. We determined that grip strengths in the range of 80lbs and 125lbs were needed to score approximately 85 % and 90 % on the PPQ, respectively; exceeding that of the average grip strength for the female officers in the study (M = 77.5lbs). Mediation analysis suggested that grip strength may mediate the relationship between officer gender and shooting performance, but studies with more power are needed to confirm that.

Conclusion: To improve shooting performance as well as public and police safety, law enforcement agencies may need to consider including grip strength training in their conditioning regime or examine the adoption pistols with a lighter trigger pull weight (e.g., 6lbs).

1. Introduction

Although the use of force, particularly lethal force, is rarely used by police officers (Baldwin et al., 2018; Bozeman et al., 2018; Parent, 2011; White, 2006), when a situation calls for the use of a firearm, officers need to be able to perform exceptionally well with respect to pistol manipulations (e.g., unholstering and aiming) and shooting accuracy. However, according to the available literature, police officers' shooting performance is subpar at best (Donner and Popovich, 2018; Lewinski et al., 2015; Morrison and Vila, 1998). The consequences of poor performance are often tragic, leading to injuries or death, both to police officers and members of the public (O'Neill et al., 2018).

In light of these concerns, police agencies have increasingly begun to evaluate factors associated with officer performance in use of force encounters (Bertilsson et al., 2020; James et al., 2019; Johnson et al., 2014). Training, skills, and stress account for a portion of the variability in shooting performance across officers (Andersen et al., 2018; Andersen and Gustafsberg, 2016; Landman et al., 2016; Vickers and Lewinski, 2012). For example, elite officers demonstrate much higher shot accuracy (75 % versus 54 %) and fewer decision errors (19 % versus 62 %) than cadets (Vickers and Lewinski, 2012). However, differences in physiology (e.g., trigger finger endurance and strength) may also impact shooting performance (Anderson and Plecas, 2000; Kayihan et al., 2013; Muirhead et al., 2019).

The current study aimed to explore the effect of grip strength and officer gender on shooting performance. More specifically, we sought to not only replicate previous findings, which have shown that grip strength is positively related to shooting performance, but to determine

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what level of grip strength might be required to achieve certain standards on tests of shooting performance. We also wanted to explore the relationship between officer gender and performance on shooting tests and determine if grip strength plays a mediating role in this relationship.

1.1. Shooting performance as a function of grip strength

An individual's grip strength involves several features of the upper body such as height, weight, forearm girth, hand length, and hand breadth (Anderson and Plecas, 2000; Kayihan et al., 2013; Rodd et al., 2010). A strong grip ensures sturdy and static shoulders, which allows one to maintain a steady position while aiming and absorbing recoil while shooting (Copay and Charles, 2001). For example, Anderson and Plecas (2000) found that officers with larger hands and longer trigger fingers displayed greater grip strength and an ability to maintain stability (by absorbing recoil) while shooting; a critical factor in shooting performance (Anderson and Plecas, 2000; Morelli et al., 2014). Similarly, Copay and Charles (2001) found that participants with a stronger grip strength were better able to pull a trigger in a smooth and more controlled manner; this ensures sight alignment is maintained and may contribute to superior shooting performance. Other studies also support these findings (e.g., Muirhead et al., 2019; Orr et al., 2017).

1.2. Differences in grip strength between male and female officers

Past research has found that female officers tend to exhibit lower levels of shooting performance compared to their male counterparts (Blaskovits et al., 2016; Charles and Copay, 2002). This difference in gender has been attributed to females, on average, having less grip strength than males (Mathiowetz et al., 1985; Nicolay and Walker, 2005; Orr et al., 2017). This suggests that if grip strength could be increased (e.g., through strength training; Dopsai et al., 2009), shooting performance would improve (Orr et al., 2017). If it is not possible to improve grip strength significantly, it may be necessary to examine other factors to enhance shooting performance, such as adjusting the trigger pull weight (i.e., the amount of pressure required to pull the trigger and fire a round) of a pistol.

1.3. Trigger pull weight

A standard issue 9 mm duty pistol typically has a trigger pull weight of approximately 4lbs–6lbs; however, this is dependent on the type of pistol used (Ayoob, 2007). There are some law enforcement agencies in North America that use double-action only (DAO) pistols. The trigger on a DAO pistol is used to both cock *and* release the hammer mechanism in order to fire, as opposed to a single-action (SA) pistol in which the trigger releases an already cocked hammer (Ayoob, 2007). Since the double-action mechanism both cocks the hammer and releases it, more leverage is required, necessitating a greater trigger pull weight. Such pistols are typically deployed with an average trigger pull weight between 9lbs and 12lbs for safety considerations (e.g., to prevent unintentional discharges; Heim et al., 2006; O'Neill et al., 2017, O'Neill et al., 2018). Despite the potential for reducing unintentional discharges by using pistols with a heavier trigger pull, other precautions should be considered if a heavy trigger pull interferes with an officer's shooting performance (Anderson and Plecas, 2000).

Trigger pull weight appears to impact shooting performance as triggers that are too heavy seem to activate additional muscles in the hand (Anderson and Plecas, 2000; Enoka, 2003; Johnson, 2007). Research suggests that the amount of force necessary to fire a pistol is equivalent to that of a firm handshake (Johnson, 2007). If the trigger pull of a firearm exceeds the force of a handshake, isolation of the index finger becomes difficult, causing the hand to engage in the use of additional muscles to complete the task of pulling the trigger. The overcompensation of unnecessary muscles, in turn, negatively affects shooting performance through involuntary hand movements (Enoka, 2003; Johnson, 2007).

1.4. Hypotheses

The current study examined the following hypotheses:

(1) gender differences will exist in shooting performance, such that male officers will outperform female officers;
(2) male officers will possess greater grip strength than female officers, and grip strength will be positively related to performance in shooting tests; and
(3) grip strength will play a mediating role when considering the relationship between officer gender and performance in shooting tests.

2. Method and materials

2.1. Participants

Information was requested from a North American law enforcement training facility that was conducting the agency mandated Police Pistol Qualification (PPQ) examination in July 2015. The facility collected demographic information, grip strength data, and PPQ scores for 118 active police officers. All participants consented to sharing their anonymized data. Participants consisted of male ($n = 86$; 72.9 %) and female officers ($n = 32$; 27.1 %), between the ages of 22 and 62 ($M = 36.2$, $SD = 7.8$), serving as active officers for an average of 7.81 years ($SD = 6.88$).[1] Most of the officers were Constables (79.6 %); the remaining officers were Corporals (14.2 %), Sergeants (5.3 %), and Staff Sergeants (0.9 %). Representative of the policing population in North America, a chi-square analysis indicated that significantly more males participated in the study relative to females, $\chi^2\,(1, 118) = 24.71, p < .001$ (Hutchins, 2015). The law enforcement agency involved approved the release of the current data for publication.

2.2. Procedure

Prior to the commencement of the PPQ, all participants completed a brief demographic questionnaire and had their grip strength recorded. The demographic questionnaire asked participants to report their age, gender, rank, and duration of service. The dominant hand grip strength of each participant was measured three consecutive times using a JAMAR Hand Dynamometer. These measurements were then averaged to obtain the mean grip strength for each officer. Each grip strength test consisted of verbal instructions to participants while holding the dynamometer in their dominant hand in a specified position (i.e., elbows flexed at 90°; Innes, 1999). The verbal instructions consisted of the following statement: "Squeeze as hard as you can … harder … harder … relax." The maximum force was recorded in pounds (lbs).

Using a DAO pistol with a trigger pull of 8lbs–12lbs, officers then took part in the PPQ to measure shooting performance. A passing score on the PPQ is mandatory for officers in the participating agency to be able to carry their duty pistol in the field. For the participating agency's PPQ, officers are required to line up and shoot at static targets from varying distances (ranging from 10 to 82 feet), in several positions (e.g., while using their non-dominant hand, from the kneeling position, and while in prone). Officers received scores based on their shooting accuracy as they progressed through five different stages involving different body positioning and firearm manipulations. Officers were obligated to acquire a total score of 200/250 (80 %) to pass.

The five stages of the PPQ under investigation in the current paper

[1] The demographic questionnaire did not provide an option for participants to identify as anything other than male or female. The researchers conducting the current study recognize this limitation.

were as follows.

The first two stages involved a focus on aim-directed fire:

Stage 1 Participants shot 14 rounds total at a target placed at a distance of 82 feet while standing (seven rounds), kneeling (five rounds), and in prone (two rounds). Participants had to obtain a minimum score of 46/70 to pass this stage.

Stage 2 Participants shot eight rounds total at a target at a distance of 49 feet while standing (four rounds) and kneeling (four rounds). Participants had 20 s to complete the stage and had to obtain a minimum score of 26/40 to pass this stage.

The last three stages focused on instinctive-reactive fire:

Stage 3 Participants shot eight rounds total at a target placed 23 feet away. They began the stage with their pistols already drawn, shot two rounds while standing to the right side of their lane and another two rounds while on the left side. They repeated this task until they had shot eight rounds. A minimum score of 26/40 was required to pass this stage.

Stage 4 Participants shot three rounds (two aimed at centre mass and one aimed at the head) at 16 feet away for four, 5-s intervals; 12 rounds are shot in total. A minimum score of 40/60 was required to pass this stage.

Stage 5 Participants shot eight rounds total (four with their dominant hand only and four with their support hand only) at a target placed 10 feet away. Officers were required to complete this stage in 15 s and obtain a minimum score of 26/40 to pass.

For the purpose of the current analyses, each participant's scores were collected from each stage and aggregated to acquire their total score out of 250.

2.3. Analytical strategy

All analyses were conducted using version 27 of SPSS (IBM Corp, 2020). First, descriptive statistics were calculated for grip strength and PPQ scores and simple inferential tests (e.g., *t*-tests, χ^2 tests) and effect sizes were used to examine groups differences (based on officer gender) and associations (between officer gender and pass/fail scores on the PPQ). Bonferroni corrections were applied when running multiple tests. Second, to examine the relationship between grip strength and PPQ scores, correlations were calculated, and logistic regression analysis was run to determine whether an officer's grip strength affected the odds of failing the PPQ. Finally, to examine the relationship between officer gender, grip strength, and shooting performance we used the PROCESS macro for SPSS (Hayes, 2017), which is a regression-based approach to mediation. When checking assumptions, one outlier with a studentized residual exceeding ± 3 was removed from the data. The sample size for that analysis was thus reduced to $n = 117$.

3. Results

3.1. Gender differences in shooting accuracy

As seen in Table 1, an independent samples *t*-test indicated that male officers ($M = 121.50$, $SD = 20.2$) had a stronger grip strength than female officers ($M = 77.5$, $SD = 13.3$), $t\,(116) = -11.41$, $p < .001$, $d = -2.36$. The PPQ scores for male and female officers are also reported in Table 1. The average PPQ score for the entire sample was 221.4/250 (88.6 %). An independent samples *t*-test revealed that the total PPQ scores were higher for male officers ($M = 225.1/250$; 90 %) compared to female officers ($M = 211.6/250$; 84.6 %), $t\,(116) = -4.17$, $p < .001$, $d = -0.86$. Significant gender differences in PPQ scores were observed across most stages of the PPQ, except for Stage 2 once the Bonferroni correction was applied.

Failure rates by officer gender are presented in Table 2, along with the results of χ^2 tests examining the association between failure and officer gender. The failure rates demonstrated that 11.9 % ($n = 14$) of participants failed the PPQ in total. Consistent with Blaskovits et al. (2016), 21.9 % ($n = 7$) of females failed (78.1 % passed, $n = 25$) the PPQ, whereas only 8.1 % ($n = 7$) of males failed (91.9 % passed, $n = 79$). After applying a Bonferroni correction to the tests, none of the χ^2 tests were significant.

3.2. Grip strength and shooting accuracy

Correlations were calculated to examine the relationship between grip strength and PPQ scores (see Fig. 1). Grip strength and overall PPQ scores were found to be moderately positively correlated, $r(117) = 0.388$, $p < .001$. Male grip strength and overall PPQ scores had a small non-significant positive correlation, $r_s(85) = 0.19$, $p = .075$. Female grip strength and overall PPQ scores had a moderate non-significant positive correlation, $r_s(32) = 0.31$, $p = .087$. The bolded solid line in Fig. 1 represents the average. The vertical reference lines in this figure indicate the average grip strengths required to score approximately 85 % and 90 % on the PPQ, which were 80lbs and 125lbs, respectively.

Logistic regression analysis was conducted to determine whether an officer's grip strength affected the odds of failing the PPQ. The grip strength of officers indicated a significant odds ratio (OR) of 1.02, (95 % CI [1.00, 1.05]). This suggests that, for every pound below the average grip strength, the odds of an officer failing the PPQ increases by 2 %.

3.3. The mediating role of grip strength

We examined the potential mediating role of grip strength when considering the relationship between officer gender and PPQ scores. As indicated above, the analysis was run using the PROCESS macro for SPSS (Hayes, 2017), a regression-based approach to mediation. All assumptions for multiple linear regression were met. Although not quite achieving statistical significance at the $p < .05$ level, likely due to being underpowered (Fritz and Mackinnon, 2007), results from the simple mediation analysis indicated that officer gender may be indirectly

Table 1
Average grip strength and PPQ scores of male and female officers.

	Total ($N = 118$)		Male ($n = 86$)		Female ($n = 32$)		*t*	*p*	*d*/Δ
	M	*SD*	*M*	*SD*	*M*	*SD*			
Grip strength	109.6	27.0	121.5	20.2	77.5	13.3	−11.41	<0.001	−2.36
Stage 1 (/70)	53.7	10.0	55.3	10.1	49.4	8.3	−2.93	0.004	−0.61
Stage 2 (/40)	33.0	6.2	33.9	5.4	30.8	7.6	−2.13	0.039	−0.41
Stage 3 (/40)	38.1	2.7	38.5	2.5	37.0	2.8	−2.72	0.008	−0.56
Stage 4 (/60)	57.8	3.6	58.4	3.3	56.4	4.0	−2.74	0.007	−0.57
Stage 5 (/40)	39.0	1.9	39.4	1.4	38.2	2.7	−2.42	0.02	−0.45
Total (/250)	221.4	16.8	225.1	15.4	211.6	16.7	−4.17	<0.001	−0.86

Note. Glass's delta (Δ) was used for Stage 2 and 5, where a significant Levene's test for equality of variances was obtained.

Table 2
PPQ pass/fail rates of male and female officers.

	Total (N = 118)		Male (n = 86)		Female (n = 32)		x^2	p	ϕ
	N	%	n	%	n	%			
Stage 1									
Pass	93	78.8 %	72	83.7 %	21	65.6 %	4.57	0.032	−0.20
Fail	25	21.2 %	14	16.3 %	11	34.4 %			
Stage 2									
Pass	105	89.0 %	80	93.0 %	25	78.1 %	5.28	0.041	−0.21
Fail	13	11.0 %	6	7.0 %	7	21.9 %			
Stage 3									
Pass	117	99.2 %	85	98.8 %	32	100.0 %	0.38	1.000	0.06
Fail	1	0.8 %	1	1.2 %	0	0.0 %			
Stage 4									
Pass	117	99.2 %	86	100.0 %	31	96.9 %	2.71	0.271	−0.15
Fail	1	0.8 %	0	0.0 %	1	3.1 %			
Stage 5									
Pass	118	100.0 %	86	100.0 %	32	100.0 %	[a]		
Fail	0	0.0 %	0	0.0 %	0	0.0 %			
Overall PPQ									
Pass	104	88.1 %	79	91.9 %	25	78.1 %	4.21	0.055	−0.19
Fail	14	11.9 %	7	8.1 %	7	21.9 %			

Note. Fisher's exact test was used when >20 % of cells had an expected count less than five.
[a] No statistics are available because Pass/Fail is a constant.

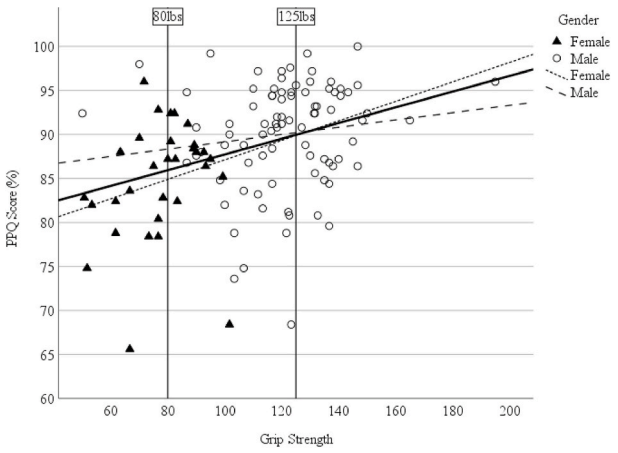

Fig. 1. Average grip strength and overall PPQ scores (%) of male and female officers.

related to PPQ score through its relationship with grip strength.

As can be seen in Fig. 2, male officers had significantly higher grip strength than female officers (a = 43.955, p < .001), and higher grip strength was subsequently related (to a near-significant degree) to higher PPQ scores (b = 0.13, p = .08). A 95 % bias-corrected confidence interval based on 10,000 bootstrap samples indicated a near-significant indirect effect (i.e., almost entirely above 0; ab = 5.705; 95 % CI = -0.319-13.219). Moreover, while male officers had significantly higher PPQ scores than female officers (c = 14.2, p < .001), this relationship became non-significant (just) after considering the indirect effect of gender on PPQ scores through grip strength (c' = .8.5, p = .06).

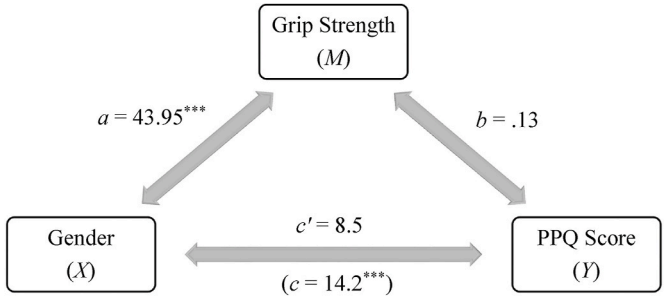

Fig. 2. The mediating effect of grip strength in the relationship between officer gender and PPQ score.
Notes: *p < .05, **p < .01, ***p < .001; All presented effects are unstandardized; a is the effect of gender on grip strength (women are coded as 0 and men as 1); b is the effect of grip strength on PPQ score; c' is the direct effect of gender on PPQ score; c is the total effect of gender on PPQ score.

4. Discussion

Below, we briefly discuss the main findings of our study, propose potential approaches for remedying problems associated with grip strength and shooting performance, speak to the potential generalizability of our results and recommendations, and highlight several study limitations.

4.1. Key findings related to officer gender, grip strength, and PPQ scores

Previous literature suggests that there may be a significant difference in shooting performance between male and female officers (Blaskovits et al., 2016; Charles and Copay, 2002). As predicted, male officers included in the current study did have, on average, higher PPQ scores compared to female officers and, consistent with prior research (e.g., Blaskovits et al., 2016), female officers failed the agency mandated PPQ at a significantly higher rate than male officers (21.9 % versus 8.1 %). It has been theorized that this finding may be attributable, at least in part, to the average grip strength of female officers, which tends to be lower than their male counterparts (Orr et al., 2017). Analyses conducted as part of this study supports this hypothesis.

Not only did male officers in this study have a higher grip strength, on average, than female officers, but we also found that it was necessary to have a grip strength that exceeded that exhibited by most female officers in our sample (M = 77.5lbs) to achieve reasonably high scores on the PPQ. More specifically, to achieve a score of 85 % on the PPQ using the pistol examined in this study, officers needed to have a grip strength of 80lbs. To achieve a 90 % score, one's grip strength would have to be approximately 125lbs. We believe this is the first time that such grip strength guidelines have been proposed for the PPQ under investigation.

Further evidence for the important role that grip strength plays in explaining the relationship between officer gender and shooting performance, and another novel contribution made in the paper, is the finding that grip strength might mediate the impact of officer gender on

PPQ scores. This result, in combination with the other findings reported in this paper, suggests that if heavy trigger weights are used without instituting minimum grip strength requirements, this will likely result in failures on the PPQ; disproportionately affecting the number of failing scores experienced by female officers. Consequentially, an absence of minimum grip strength requirements may also thereby pose increased risk to public and police safety.

While we didn't investigate exactly why grip strength influences shooting performance in the current study, previous research has highlighted the sorts of complications that can arise when using a firearm with a trigger pull weight that is incompatible with grip strength. For example, when one has a weaker grip in relation to a firearm's trigger weight, this can result in officers using a tight grip for an extended period. This can cause a restriction of blood flow, which can lead to tremors and involuntary muscle contractions that increase the odds of moving sights out of alignment when shooting and impact an officer's ability to absorb recoil and engage in target re-acquisition (Johnson, 2007; Tully, 1996, 1997). A tight grip can also decrease the time that the hand can function before it becomes fatigued (Anderson and Plecas, 2000; Johnson, 2007; Nicolay and Walker, 2005).

4.2. Methods for remedying challenges associated with insufficient grip strength

Readers should refrain from concluding that our findings suggest that female officers (or male officers with a lower-than-average grip strength) will necessarily fail the PPQ at high rates, or that they will exhibit poor performance in the field. Indeed, there are many factors that could potentially counter the effects observed in the current study. Perhaps one of the most obvious options is strength training. Previous research has suggested that strength training may assist in reducing grip strength differences between male and female officers (Leyk et al., 2007). The current study also demonstrates that female officers perform at a rate comparable to male officers – with a heavy trigger weight – when their grip strengths are equivalent. However, research suggests that it is difficult for females to achieve high levels of grip strength, even with strenuous strength training (Arvey et al., 1992; Dopsai et al., 2009).

Considering this, another option that must be considered involves making changes to the weight of pistol trigger pulls. This may have a significant impact on reducing any gender differences in PPQ performance, or at least aligning grip strength with trigger pull to maximize the performance of all officers. While additional research is needed to assess the impact that different trigger pull weights have on shooting performance in PPQ-type tests, it is quite clear based on the results from the current study that the 8lbs–12lbs trigger pull that characterizes the pistol examined in this study may simply not be optimal for all officers (but particularly female officers); encouraging the adoption of pistols with lighter trigger weights (e.g., 6lbs) to allow for compatibility between trigger pull weight and grip strength.

4.3. The generalizability of our findings

Questions worth asking at this stage are whether the findings reported in this study are likely to generalize to other samples of police officers and whether the recommendations outlined above for remedying the challenges associated with grip strength and shooting performance are likely to be useful beyond the police agency examined here. Although direct replication attempts are required to answer these questions, we believe there are consistencies between our findings and those reported in previous research, which suggest that our results, and our recommendations, are broadly applicable.

As mentioned, the lower level of shooting performance exhibited by female (versus male) officers in our sample is consistent with previous research conducted in other settings (e.g., Charles and Copay, 2002). In addition, the overall moderate positive correlation that we found between grip strength and PPQ scores ($r = 0.388$) corresponds with the results ($r = 0.38$) reported by Anderson and Plecas (2000). Furthermore, the actual grip strength of our male and female officers corresponds with those reported in other studies. Recall that male officers in our study had an average grip strength of 121.50lbs, which was significantly higher than female officers, who had an average grip strength of 77.5lbs. In their study of 597 male and 34 female police officers, Dawes et al. (2017) found that male and female officers had average grip strengths of 121.3lbs and 83.5lbs, respectively. Statistical tests reveal that these findings do not differ significantly across studies.

Even our recommendation that agencies consider lowering the weight of pistol trigger pulls, especially for those with lower grip strength, appears to be supported by previous research. For example, Anderson and Plecas (2000) found that those shooting with a Beretta model 94F (~11lbs trigger pull weight) obtained significantly lower shooting scores than those using the Glock model 22 (~5.5lbs trigger pull weight), regardless of gender.

4.4. Study limitations

This study had several limitations that warrant discussion. First, given participants' time constraints, we could not collect additional demographic variables (e.g., experience with firearms), anthropometric data (e.g., hand measurements) or training information (e.g., specialized firearms training), that may have helped shed light on the findings. Future research in this area should examine these variables and explore how they relate to the variables studied here (i.e., officer gender, grip strength, and shooting performance). Second, notwithstanding the arguments above that many of our results are consistent with previous research, because our sample relied on police officers from only one agency, it is possible that our findings might not generalize beyond those tested here. For example, different findings may emerge for different types of pistols or if officers were to shoot for another type of PPQ. Replication studies should be conducted to directly assess generalizability. Lastly, while our sample was larger than those used in other studies of shooting performance (e.g., Anderson and Plecas, 2000), our study was still underpowered. Sample size was a particular issue for the mediation analysis. To achieve sufficient power for the effect sizes observed, a significantly larger sample (i.e., $N = \sim400$) would be required to achieve 80 % power (Fritz and Mackinnon, 2007). Researchers should conduct similar analyses in the future with larger samples.

5. Conclusion

Our analysis revealed a higher rate of failing on the PPQ for female officers, but other analyses suggest that failure on the PPQ may not be due to officer gender, but rather the heavy trigger weight of the duty pistol used by officers in our sample. Compared to male officers, female officers may not have the grip strength necessary to perform well throughout the five stages of the PPQ we examined. At the present time, the police service that participated in the study might consider introducing grip strength training into an officer's conditioning regime or consider moving to a pistol with a lower trigger pull weight. This should improve scores on the agency mandated PPQ. Although research is still required to determine the link between PPQ scores and shooting performance in real-world use of force encounters (Morrison and Vila, 1998), we would also speculate that addressing the issues with grip strength will likely have a positive impact on both police officer and public safety in the field as well.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: During the completion of the current study, three of the four authors were employed by the policing agency that facilitated the study. However, the findings of this paper are in no way representative of the opinions of the agency.

References

Andersen, J.P., Gustafsberg, H., 2016. A Training Method to Improve Police Use of Force Decision Making: A Randomized Controlled Trial. Sage Open, pp. 1–13.

Andersen, J.P., Di Nota, P.M., Beston, B., Boychuk, E.C., Gustafsberg, H., Poplawski, S., Arpaia, J., 2018. Reducing lethal force errors by modulating police physiology. J. Occup. Environ. Med. 60 (10), 867–874. http://doi:10.1097/jom.0000000000001401.

Anderson, G.S., Plecas, D.B., 2000. Predicting shooting scores from physical performance data. Policing 23 (4), 525–537.

Arvey, R.D., Landon, T.E., Nutting, S.M., Maxwell, S.E., 1992. Development of physical ability tests for police officers: a construct validation approach. J. Appl. Psychol. 77 (6), 996.

Ayoob, M., 2007. The Gun Digest Book of Combat Handgunnery, sixth ed. Iola, Wisconsin.

Baldwin, S., Hall, C., Blaskovits, B., Bennell, C., Lawrence, C., Semple, T., 2018. Excited delirium syndrome (ExDS): situational factors and risks to officer safety in non-fatal use of force encounters. Int. J. Law Psychiatr. 60, 26–34. http://doi:10.1016/j.ijlp.2018.06.011.

Bertilsson, J., Niehorster, D.C., Fredriksson, P.J., Dahl, M., Granér, S., Fredriksson, O., Nyström, M., 2020. Towards systematic and objective evaluation of police officer performance in stressful situations. Police Pract. Res. 21 (6), 655–669. http://doi:10.1080/15614263.2019.1666006.

Blaskovits, B., Mugford, R., Baldwin, S., Bennell, C., 2016. Factors Influencing Police Officer Performance and Retention in Police Pistol Qualification Tests. Society for Police and Criminal Psychology Conference, Austin, Texas.

Bozeman, W.P., Stopyra, J.P., Klinger, D.A., Martin, B.P., Graham, D.D., Johnson, J.C.I., Vail, S.J., 2018. Injuries associated with police use of force. J. Trauma Acute Care Surg. 84 (3), 466–472. http://doi:10.1097/ta.0000000000001783.

Charles, M.T., Copay, A.G., 2002. Acquisition of marksmanship and gun handling skills through basic law enforcement training in an American police department. Int. J. Police Sci. Manag. 5 (1), 16–30. https://doi:10.1350/ijps.5.1.16.11245.

Copay, A.G., Charles, M.T., 2001. The influence of grip strength on handgun marksmanship in basic law enforcement training. Policing 24 (1), 32–39.

Dawes, J.J., Orr, R.M., Flores, R.R., Lockie, R.G., Kornhauser, C., Holmes, R., 2017. A physical fitness profile of state highway patrol officers by gender and age. Ann. Occup. Environ. Med. 29 (1), 1–11.

Donner, C.M., Popovich, N., 2018. Hitting (or missing) the mark: an examination of police shooting accuracy in officer-involved shooting incidents. Policing 42 (3), 474–489. http://doi:10.1108/PIJPSM-05-2018-0060.

Dopsai, M., Ivanovic, J., Blagojevic, M., Koropanovski, N., Vuckovic, G., Jankovic, R., et al., 2009. Basic and specific characteristics of the hand grip explosive force and time parameters in different strength trained population. Braz. J. Biomotricity 3 (2), 177–193.

Enoka, R.M., 2003. Involuntary muscle contractions and the unintentional discharge of a firearm. Law Enforc. Exec. Forum 3 (2), 27–39.

Fritz, M.S., Mackinnon, D.P., 2007. Required sample size to detect the mediated effect. Psychol. Sci. 18 (3), 233–239. http://doi:10.1111/j.1467-9280.2007.01882.x.

Hayes, A.F., 2017. Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach, second ed. Guilford Press, New York.

Heim, C., Schmidtbleicher, D., Niebergall, E., 2006. The risk of involuntary firearm discharge. Hum. Factors 48, 413–421. https://doi:10.1518/001872006778606813.

Hutchins, H, 2015. Police resources in Canada, 2014. Juristat: Can. Centre Just. Statist. 1.

IBM Corp, 2020. IBM SPSS Statistics for Windows (Version 27.0). IBM Corp, Armonk, NY.

Innes, E., 1999. Handgrip strength testing: a review of the literature. Aust. Occup. Ther. J. 46 (3), 120–140.

James, L., James, S., Davis, R., Dotson, E., 2019. Using interval-level metrics to investigate situational-, suspect-, and officer-level predictors of police performance during encounters with the public. Police Q. 22 (4), 452–480. http://doi:10.1177/1098611119857559.

Johnson, B.R., 2007. Crucial Elements of Police Firearm Training. Looseleaf Law Publications, New York, pp. 157–195.

Johnson, R.R., Stone, B.T., Miranda, C.M., Vila, B., James, L., James, S.M., Berka, C., 2014. Identifying psychophysiological indices of expert vs. novice performance in deadly force judgment and decision making. Front. Hum. Neurosci. 8, 512. http://doi:10.3389/fnhum.2014.00512.

Kayihan, G., Ersöz, G., Özkan, A., Mitat, K., 2013. Relationship between efficiency of pistol shooting and selected physical-physiological parameters of police. Policing 36 (4), 819–832.

Landman, A., Nieuwenhuys, A., Oudejans, R.R.D., 2016. The impact of personality traits and professional experience on police officers' shooting performance under pressure. Ergonomics 59 (7), 950-912. http://doi:10.1080/00140139.2015.1107625.

Lewinski, W.J., Avery, R., Dysterheft, J., Dicks, N.D., Bushey, J., 2015. The real risks during deadly police shootouts: Accuracy of the naive shooter. Int. J. Police Sci. Manag. 17 (2), 117–127.

Leyk, D., Gorges, W., Ridder, D., Wunderlich, M., Rüther, T., Sievert, A., Essfeld, D., 2007. Hand-grip strength of young men, women and highly trained female athletes. Eur. J. Appl. Physiol. 99 (4), 415–421.

Mathiowetz, V., Kashman, N., Volland, G., Weber, K., Dowe, M., Rogers, S., 1985. Grip and pinch strength: normative data for adults. Arch. Phys. Med. Rehabil. 66 (2), 69–74.

Morelli, F., Neugebauer, J.M., LaFiandra, M.E., Burcham, P., Gordon, C.T., 2014. Recoil measurement, mitigation techniques, and effects on small arms weapon design and marksmanship performance. IEEE Trans. Hum. Mach. Syst. 44 (3), 422–428. https://doi:10.1109/THMS.2014.2301715.

Morrison, G.B., Vila, B.J., 1998. Police handgun qualification: practical measure or aimless activity? Policing 21 (3), 510–533. https://doi:10.1108/13639519810228804.

Muirhead, H., Orr, R., Schram, B., Kornhauser, C., Holmes, R., Dawes, J.J., 2019. The relationship between fitness and marksmanship in police officers. Saf. Now. 5 (3), 54. http://doi:10.3390/safety5030054.

Nicolay, C.W., Walker, A.L., 2005. Grip strength and endurance: influences of anthropometric variation, hand dominance, and gender. Int. J. Ind. Ergon. 35 (7), 605–618. https://doi:10.1016/j.ergon.2005.01.007.

O'Neill, J., O'Neill, D.A., Lewinski, W.J., 2017. Toward a taxonomy of the unintentional discharge of firearm in law enforcement. Appl. Ergon. 59, 283–292.

O'Neill, J., Hartman, M.E., O'Neill, D.A., Lewinski, W.J., 2018. Further analysis of the unintentional discharge of firearms in law enforcement. Appl. Ergon. 68, 267–272.

Orr, R., Pope, R., Stierli, M., Hinton, B., 2017. Grip strength and its relationship to police recruit task performance and injury risk: a retrospective cohort study. Int. J. Environ. Res. Publ. Health 14 (8), 941.

Parent, R., 2011. The police use of deadly force in British columbia: mental illness and crisis intervention. J. Police Crisis Negot. 11 (1), 57–71. http://doi:10.1080/15332586.2011.548144.

Rodd, D., Leasure-Woodburn, M., Wilson, G., 2010. The effects of grip strength and firearm discharge. Indiana Law Enforc. J. 1 (8), 1–11.

Tully, E., 1996. Unintentional discharge of police weapons. Blue Line Magaz. 8 (10), 18–21.

Vickers, J.N., Lewinski, W.J., 2012. Performing under pressure: gaze control, decision making and shooting performance of elite and rookie police officers. Hum. Mov. Sci. 31 (1), 101–117.

White, M.D., 2006. Hitting the target (or not): comparing the characteristics of fatal, injurious, and non-injurious police shootings. Police Q. 9 (3), 303–330.