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ORIGINAL ARTICLE

Prevalence of the Linburg–Comstock variation through clinical evaluation

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Abstract

Introduction Linburg–Comstock variation, the tendinous interconnection between flexor pollicis longus and flexor digitorum profundus, is known to have a wide frequency range. Its prevalence is reported with a range of 13–66%. The aim of the study was to assess this variation in general population and to correlate it with gender and side.

Material and methods This prospective study included 215 subjects (82 males and 133 females). Two clinical tests were conducted to diagnose the variation and to detect any related symptomatology. The primary outcome was set to be the prevalence of Linburg–Comstock variation. Secondary outcomes were defined as gender-based prevalence, side-based prevalence, and Linburg–Comstock variation prevalence association with gender and side.

Results Linburg–Comstock variation was clinically diagnosed in 130 (60.47%) participants. Unilateral and bilateral prevalence were of 17.21% and 43.26%, respectively, yielding a statistically significant difference. Right-sided and left-sided presence were calculated at 7.44% and 9.77%. Bilateral prevalence was statistically more common in females. Right-sided variation was found to be more frequent in males while left-sided variation was more prevalent in females. The index finger was the most commonly involved with prevalence of 91.03%. Symmetry was noted in 67.74% of subjects.

Conclusion The results of our study demonstrated a relatively high prevalence of the Linburg–Comstock variation in Serbian population. We noted a few unusual cases and this finding point to the existence of the broader spectrum of Linburg–Comstock variation, and complexity of the flexor apparatus of the hand, so, further investigations about this topic are needed to improve our knowledge. Due to the possibility of false-positive result during clinical testing we suggest to use expanded clinical method.

Keywords Linburg–Comstock variation · Flexor pollicis longus · Flexor digitorum profundus · Hand

Introduction

The presence of an anomalous interconnection between flexor pollicis longus (FPL) and flexor digitorum profundus (FDP) tendons was described during the second half of the nineteenth century [7, 12, 20, 23–25]. Linburg and Comstock were the first to report clinical and cadaveric frequency of this variation in humans [9]. It represents an anomalous connection between FPL and mostly FDP of the index finger but rarely, FDP tendons of the other long fingers, or in some sporadic cases the first lumbrical muscle, have been reported to be involved. The tendinous interconnection is most often based proximally originating from the FPL and extending obliquely downward to the FDP. Therefore, during the active thumb flexion, contraction of the FPL will pull the tendinous connection upward which results in simultaneous flexion of the involved digit(s) while an independent active flexion of

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the index finger or the other involved fingers cannot provoke simultaneous flexion of the thumb [13, 18].

Clinical finding depends on the location and size of the tendinous connection, the involved finger(s), and occupation of the person. Linburg–Comstock variation (LCV) could be located at the level of the forearm, wrist or hand [9, 10]. The observed tendinous connection could be musculo-tendinous, tendinous or fibrous, with a wide range of thickness variation [27]. The index finger alone or along with the middle and ring finger is the most involved finger [13, 18]. Although asymptomatic in most cases, pain and swelling could be present in about 2% of LCV cases [13]. Flexor tenosynovitis and carpal tunnel syndrome were reported to be caused by LCV. Some occupations, especially musicians with LCV, represent a risk group for the development of LC syndrome (LCS) because of repetitive and independent finger and hand movements [6].

It is interesting to note that, although this variation is quite prevalent and may cause career-threatening disabilities or could complicate some hand injuries, only a few clinical studies have reported the prevalence of the LCV [1, 3–6, 9, 11, 13–15, 17], ranging from 13 to 66% [5, 13]. A recent meta-analysis revealed a clinical frequency of 24.3% in the general population with a bilateral and unilateral prevalence of 12% and 11.8%, respectively [26]. We assume that LCV is frequently present in our population, equally bilaterally and unilaterally.

Therefore, this prospective study was conducted to determine the prevalence of the LCV in Serbian population, to correlate it with gender and body side of subjects and to analyze the frequency of the involvement of different fingers.

Materials and methods

The study included 215 University students (82 males and 133 females) with a mean age of 19.61 ± 0.83 years (ranged from 18 to 23). We analyzed 430 forearms. Only subjects willing to participate and who have had full range of movement of their hand and wrist joints were included in the study. Individuals with a history of injury, weakness, pain, neuromuscular disease or anomaly of upper extremities that would preclude examination for the presence of the LCV were excluded from the study. The study was approved by the independent Ethics Committee of the Faculty of Medicine. A single examiner conducted the physical examination. The clinical assessments consisted of two consecutive tests (Fig. 1):

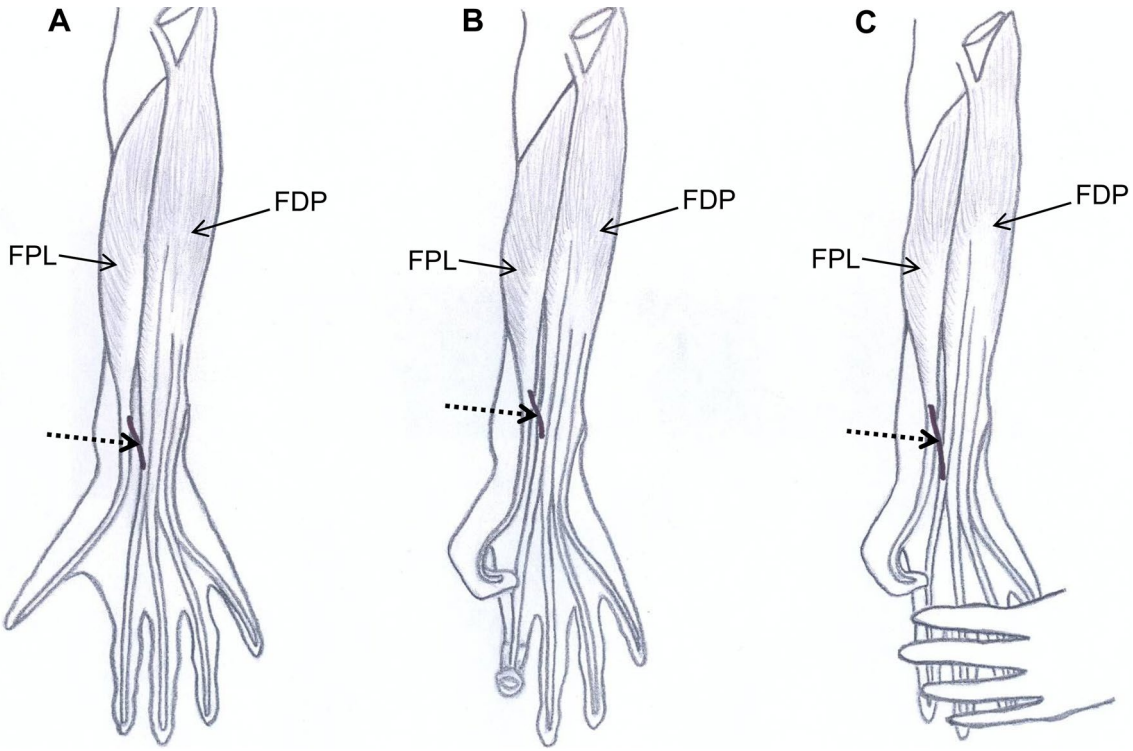

Fig. 1 Tendinous interconnection (dashed arrow) based proximally originating from the flexor pollicis longus (FPL) and extending obliquely downward to the flexor digitorum profundus (FDP): neutral position (**a**); simultaneous flexion of the index finger during active flexion of the thumb (**b**); stretching of the tendinous interconnection during active flexion of the thumb while examiner holds long fingers in full extension (**c**)

- Study subjects were asked to do active flexion of the thumb. Inability to flex the thumb without simultaneous involuntary flexion of the index finger (or/and the other long fingers) is considered as a positive result and was noted in the study protocol [9, 22].
- Continuation of the clinical examination entailed keeping the wrist in supination and neutral extension and positive result was confirmed by the appearance of pain or discomfort during active flexion of the thumb, while the long fingers were held out in full extension by the examiner [9, 13–15, 22].

Statistical analysis was carried using SPSS 25.0.0.0 software. The one-way ANOVA and Chi-square test were conducted to look for significant differences between groups of comparison.

Results

All subjects included in the study were asymptomatic. The crude prevalence of LCV (unilateral and bilateral) was 60.47% ($n=130$). In comparison to the unilateral, bilateral prevalence was more common, yielding a statistically significant difference ($X^2=34.57$; $p=0.000$). This variation was present on the right side in 16 (7.44%) and on the left side in 21 (9.77%) subjects but difference was not statistically significant (Table 1). This implies that there is 71.54% probability of a subject with one-sided LCV to have this variation on the opposite side as well. If the LCV was absent in one hand, the probability of absence in the opposite hand was 69.67%.

In males, unilateral prevalence of LCV was 17.07% ($n=14$) while bilateral prevalence was 29.27% ($n=24$). The difference between unilateral and bilateral prevalence as well as difference between right and left side in males did not reach statistical significance. The crude prevalence of LCV (unilateral and bilateral) was 46.34% ($n=38$). There was a 63.16% probability of a male subject with one-sided LCV to have variation on the opposite side.

In females, unilateral prevalence of LCV was 17.29% ($n=23$) while bilateral prevalence was 51.88% ($n=69$), yielding a statistically significant difference between the unilateral and bilateral prevalence ($X^2=35.16$, $p=0.000$). There was no significant difference between right and left side in females. The crude prevalence was 69.17% ($n=92$). In a case of one-sided LCV in a female subject, there was a 75% chance that variation will be also present on the other side.

Hence, bilateral prevalence was more common in females than in males, the difference was statistically significant ($X^2=10.56$; $p=0.001$). Right-sided prevalence was more frequent in males while left-sided prevalence was frequently seen in females but the difference between them was not statistically significant.

The difference in crude prevalence of LCV between males and females was almost 23%. Gender difference in the crude prevalence of the LCV was statistically significant ($X^2=11.06$, $p=0.000$).

The most involved digit was the index finger and along with the other three digits had a prevalence of 91.03%. The index finger on its own was independently involved in 54.71% (Table 2, Figs. 2 and 3) whereas the middle finger was involved independently in 8.97% subjects. The ring and the little finger were involved along with the index and middle finger demonstrating a prevalence of 5.83%.

Table 1 Linburg–Comstock variation prevalence according to gender and limb laterality

LC variation	No. of subjects	%	Male	%	Female	%
Bilateral presence	93	43.26	24	29.27	69	51.88
Right presence	16	7.44	9	10.98	7	5.26
Left presence	21	9.77	5	6.10	16	12.03
Bilateral absence	85	39.53	44	53.66	41	30.83
Total	215	100	82	38.14	133	61.86

Table 2 Involved finger(s) according to gender and limb laterality

Finger(s)	No. of subjects		Male		Female	
	Right hand	Left hand	Right hand	Left hand	Right hand	Left hand
II	58 (26.98%)	64 (29.77%)	20 (24.39%)	19 (23.17%)	38 (28.57%)	45 (33.83%)
III	11 (5.12%)	9 (4.19%)	1 (1.22%)	1 (1.22%)	10 (7.52%)	8 (6.02%)
II + III	35 (16.28%)	33 (15.35%)	12 (14.62%)	7 (8.54%)	23 (17.29%)	26 (19.55%)
II + III + IV	4 (1.86%)	6 (2.79%)	–	2 (2.44%)	4 (3.01%)	4 (3.01%)
II + III + IV + V	1 (0.47%)	2 (0.93%)	–	–	1 (0.75%)	2 (1.50%)
Total	109 (50.70%)	114 (53.02%)	33 (40.24%)	29 (35.37%)	76 (57.14%)	85 (63.91%)

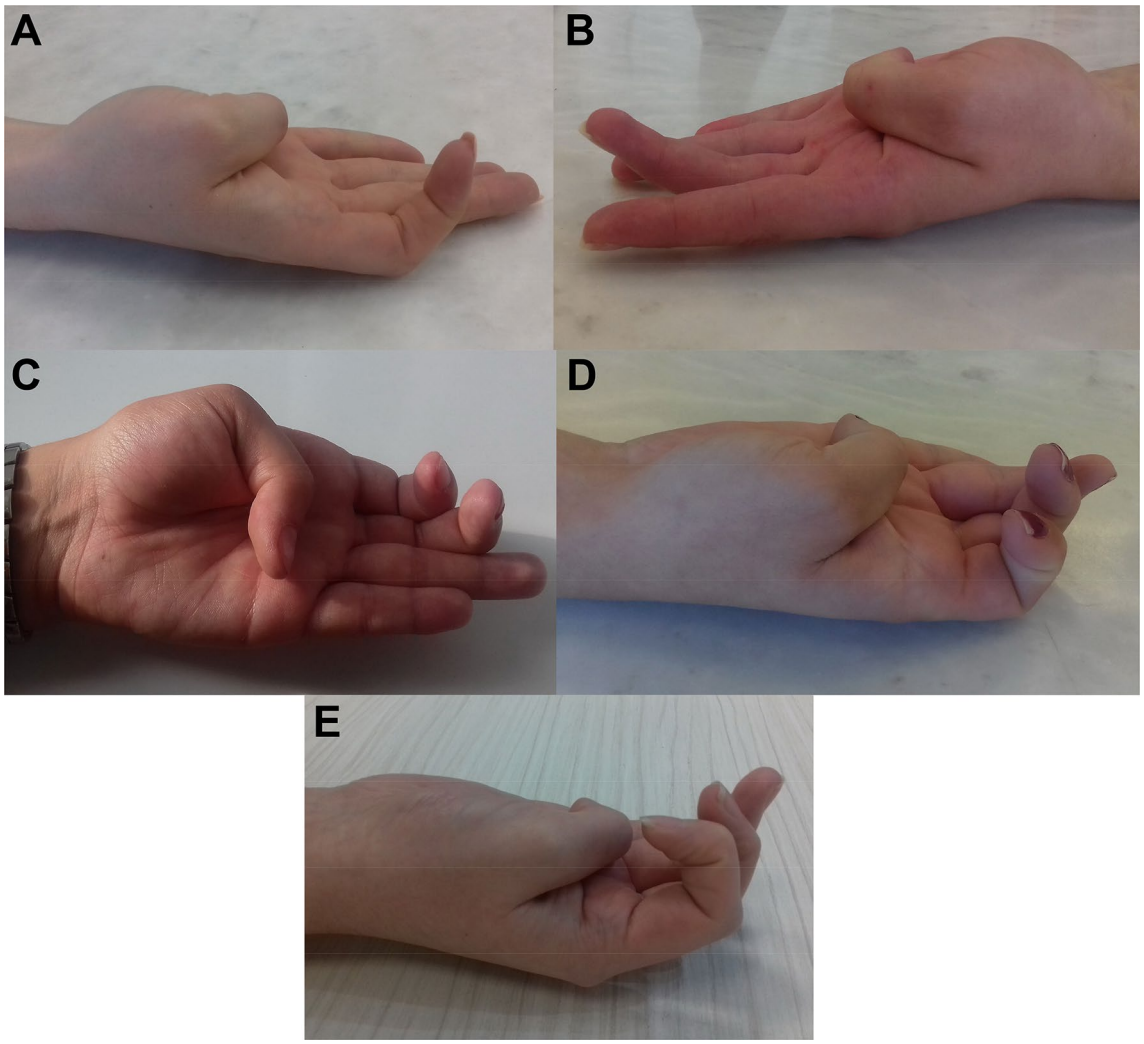

Fig. 2 Involved fingers: index finger (**a**); middle finger (**b**); index and middle finger (**c**); index, middle and ring finger (**d**); four fingers (index finger to little finger—**e**)

According to ANOVA, there were statistically significant differences among the involved fingers ($f = 16.63$; $p = 0.000$). One finger was involved in 63.68% while two or more fingers were involved in 36.32% (Table 2). Out of the total number of bilateral prevalence of the LCV ($n = 93$, 43.26%), symmetry was seen in 63 (67.74%) subjects. Index finger was involved bilaterally in 39 (61.90%) subjects, middle finger in 4 (6.35%) subjects, jointly index and middle finger in 17 (26.98%) subjects, index and middle finger along with the ring finger in 2 (3.17%) subjects and four fingers (index finger to little finger) in 1 (1.59%) subject. We noted ten unusual cases of LCV (Fig. 4). Also, 24 (11.16%) asymptomatic subjects were able to do independent active flexion of the thumb but they experienced pain or discomfort at the level of the forearm, wrist or hand only during the provocative testing.

Discussion

Although LCV is quite prevalent, but it is still frequently unrecognized and most often, does not receive the attention it deserves. Comparison of our results with those reported from the other ethnic group studies conducted in Saudi [1], Italian [3], French [4], Turkish [5, 6, 14], American [9, 17], Malaysians [11], British [13] and Canadian [15] population (Table 3) revealed the presence of LCV to be more pronounced in our population. Our results are similar to those obtained by Miller et al. They reported a positive Linburg–Comstock test result for 60–70% of subjects in both investigated groups (musicians and non-musicians) [13]. The results of our study show a relatively high prevalence of the LCV (60.47%) and point to more

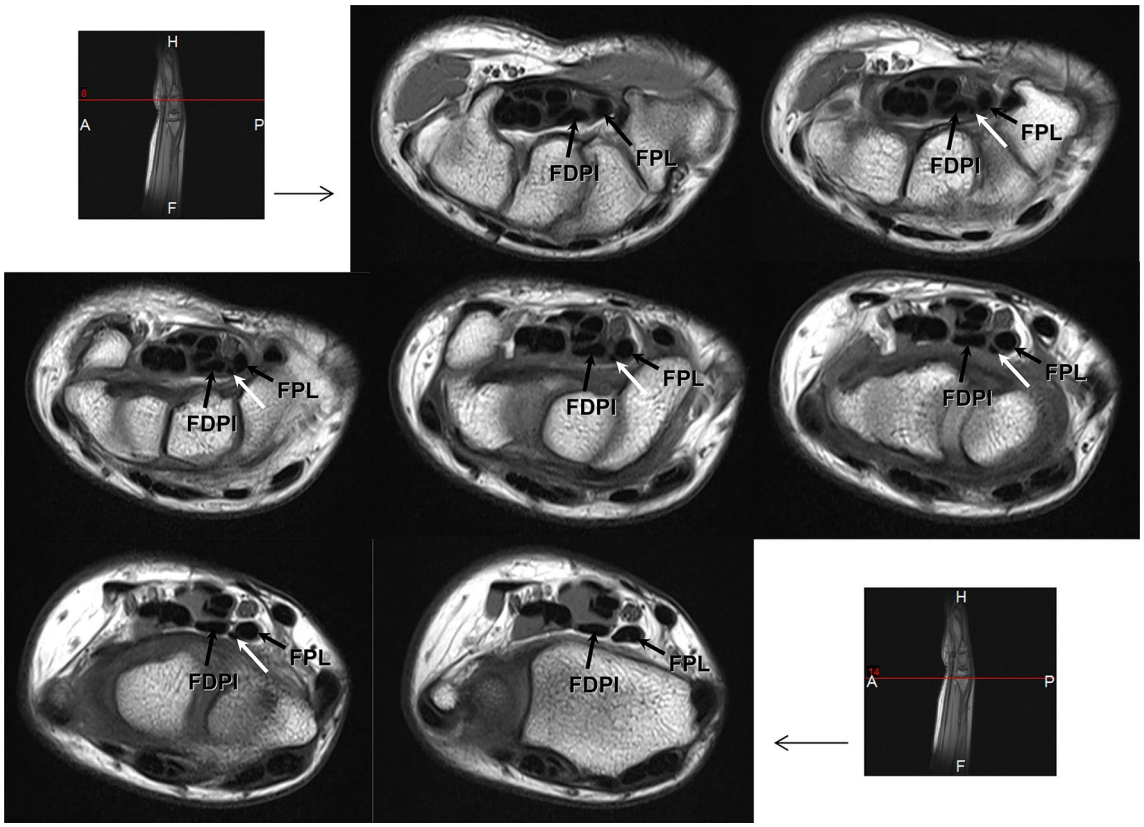

Fig. 3 Axial MRI images of the hand and distal forearm illustrating tendinous interconnection (white arrow) between flexor digitorum profundus of the index finger (FDPI) and flexor pollicis longus (FPL)

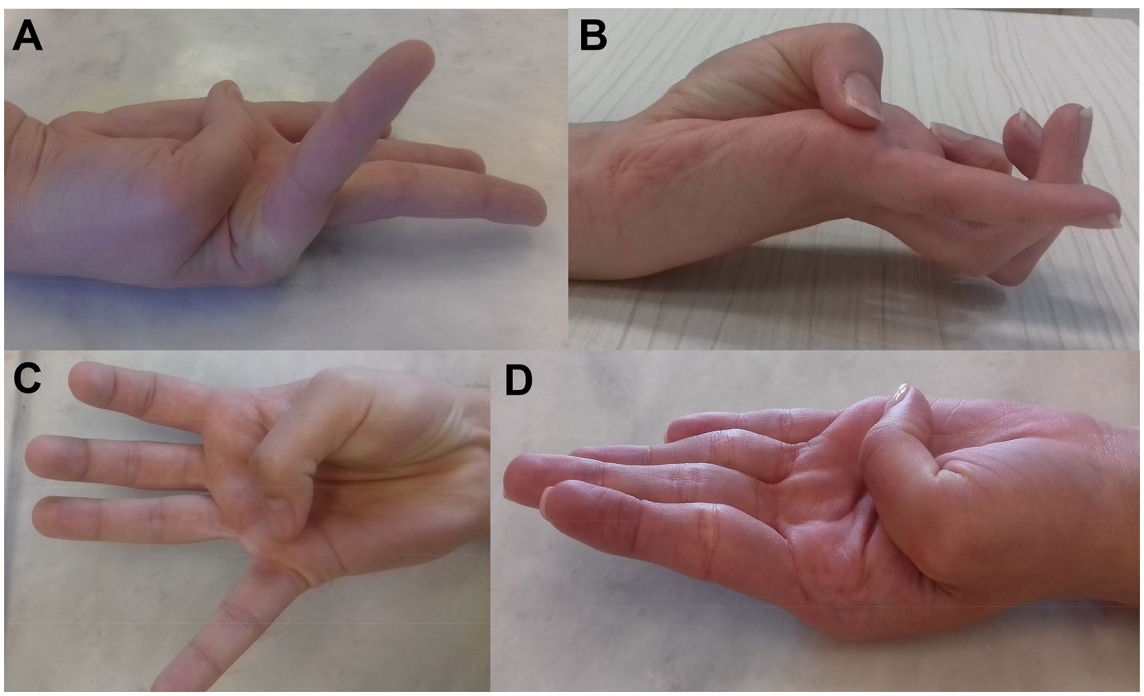

Fig. 4 Unusual cases of LCV: flexed metacarpophalangeal joint and extended interphalangeal joints of the forefinger (**a**); hyperextended metacarpophalangeal joints (**b**); abducted little finger (**c**); hyperextended proximal interphalangeal joints (**d**)

Table 3 Prevalence of Linburg–Comstock variation in various ethnic groups

Studies	Ethnicity	Number of subjects	Crude prevalence	Male prevalence	Female prevalence	Bilateral prevalence	Unilateral prevalence	Number of hands	True prevalence	Right prevalence	Left prevalence
Alzahrani et al., 2018 [1]	Saudi	331	129 (38.97)	70 (42.68)	59 (35.33)	43 (12.9%)	86 (25.98)	662	172 (25.98)	94 (28.40)	78 (23.56)
Cigni, 2010 [3]	Italian	100	15 (15.00)	7 (14.00)	8 (16.00)	6 (6.00)	9 (9.00)	200	21 (10.50)	13 (13.00)	8 (8.00)
Hamitouche et al., 2000 [4]	French	264	98 (37.12)	28 (21.21)	70 (53.03)	82 (31.06)	16 (6.06)	528	180 (34.09)	NR	NR
Karalezli et al., 2006 [5]	Turkish	52	9 (17.31)	NR	NR	4 (7.69)	5 (9.62)	104	13 (12.5)	NR	NR
Karalezli et al., 2006 [6]	Turkish	136	18 (13.24)	7 (10.14)	11 (16.4)	6 (4.4)	12 (8.8)	272	24 (8.82)	13 (9.56)	11 (8.09)
Linburg and Comstock, 1979 [9]	American	194	61 (31.44)	NR	NR	28 (14.43)	33 (17.01)	388	89 (22.94)	NR	NR
Low et al., 2012 [11]	Malaysian	292	102 (34.93)	55 (42.30)	47 (29.01)	35 (11.98)	67 (22.95)	584	137 (23.46)	73 (25.00)	64 (21.92)
Miller et al., 2003 (*Musicians*) [13]	British	86	NR	NR	NR	NR	NR	172	101 (58.72)	47 (54.65)	54 (62.79)
Miller et al., 2003 (*Non-musicians*) [13]	British	55	NR	NR	NR	NR	NR	110	64 (58.18)	28 (50.91)	36 (65.45)
Ortak et al., 2007 [14]	Turkish	108	40 (37.04)	NR	NR	28 (25.93)	12 (11.11)	216	68 (31.48)	36 (33.33)	32 (29.63)
Rennie and Muller, 1998 [15]	Canadian	200	40 (20.00)	17 (18.89)	23 (20.90)	14 (7.00)	26 (13.00)	400	54 (13.50)	31 (15.50)	23 (11.50)
Schraut et al., 2015 [17]	American	184	25 (13.59)	10 (5.43)	15 (8.15)	16 (8.70)	9 (4.89)	368	41 (11.14)	24 (13.04)	17 (9.24)
Our study	Serbian	215	130 (60.47)	38 (46.34)	92 (69.17)	93 (43.26)	37 (17.21)	430	223 (51.86)	109 (50.70)	114 (53.02)

The values between parentheses are the percentage values

NR not reported

pronounced unilateral presence of this variation on left side in general population. Bilateral prevalence was significantly more common than unilateral prevalence (43.26% vs. 17.21%). While some authors reported similar finding [4, 14, 17] a larger number of studies indicated a higher unilateral prevalence [1, 3, 5, 6, 9, 11, 15]. Overall prevalence of LCV was significantly more common in females (46.34% vs. 69.17%), as well as bilateral prevalence (29.27% vs. 51.88%). Until now, only two studies reported a higher prevalence of LCV in males [1, 11].

The authors of the recently published meta-analysis found significantly higher LCV rate in females compared to males but no significant difference was found for laterality. Also, according to the results of their study Turkish population demonstrated a significantly higher crude frequency when compared to Europeans [26]. Thus, high prevalence of LCV in our population might be explainable by historical presence of the Turks in this region.

Comparable to the results of the other authors, the index finger was the most involved of all four digits, but unusually, we noted some cases with independent involvement of the middle finger (8.97%). Until now, only one study has reported connection between FPL and FDP of the ring (and little) finger along with the index and middle finger [13]. These cases are rare and according to the results of our study their frequency was found to be 5.83%.

Additionally, we noted a few unusual cases of LCV variation. In some individuals provocative testing for the possible presence of LCV results in flexed metacarpophalangeal joint and extended interphalangeal joints of the index finger, hyperextended metacarpophalangeal joints of long fingers, abducted little finger, hyperextended proximal interphalangeal joints of long fingers. Also, we noted 24 (11.16%) cases without any involuntary movement but they complained of pain or discomfort during provocative testing for LCV so these subjects could represent some milder forms of the LCV. Hence, all these findings point to the existence of the broader spectrum of LCV and complexity of the flexor apparatus of the hand. Moreover, considering the high prevalence of LCV in general population, surgeons should be careful when treating flexor tendon injuries. Few authors identified LCV as a possible cause of an early rupture of a repaired FPL tendon in cases where only the thumb was splinted [2, 19, 21]. In musicians, especially string players, at the beginning LCV is the most usually asymptomatic but over time it may cause career-threatening disabilities and problems like pain, swelling, tenosynovitis and carpal tunnel syndrome [6, 13]. On the other hand, in security members, during weapons handling it may lead to fatal accident [14].

Searching the literature about prevalence of the LCV, the authors of this paper noticed that some of the previously published studies interpreted inability to flex the distal joint of the thumb without involuntary flexion of the index finger (or/and the other long fingers) as a positive result. However, other studies expanded the clinical examination by passive restriction of flexion of the long fingers while the thumb is actively flexed. Presence of pain or discomfort confirmed a positive result and presence of the LCV [9, 13–15]. Due to the possibility of false-positive results, we recommend the use of expanded clinical examination. That is, active flexion of the thumb without passive restriction of flexion of the other fingers (simultaneous involuntary flexion of the index finger or/and the other long fingers—objective finding) and active flexion of the thumb while the long fingers are held in full extension by the examiner (pain or discomfort—subjective finding). There is anatomical explanation of these tests: during the active thumb flexion, contraction of the FPL will pull the tendinous interconnection upward which results in simultaneous flexion of the involved digit(s); active flexion of the thumb while the long fingers are held in full extension will result in stretching of the tendinous interconnection which produces pain or discomfort.

For example, focal dystonia could be a cause of false-positive results. This painless condition also called focal hand dystonia causes involuntary or unusual movements and affects predominantly, fingers and hands [8]. On the other hand, patients with LCV, even after an excision of the tendinous interconnection, may still complain of persisting involuntary flexion of the involved finger(s) and hence it is advisable to re-learn the specific motor task to assist with improving motor control; LCV is a congenital condition and some functional deficits are present during the entirety of patient`s life [16]. In symptomatic cases with positive clinical tests, dynamic ultrasound should be performed for the purpose of LCV visualization and locating of the tendinous interconnection.

We are aware that these clinical studies may have some limitations, such as the difficulty in diagnosing anatomical variations of FPL and FDP muscles depending solely on physical examination. One of the possible limitations of this study could be a presence of the Gantzer muscle which represents accessory head of the FPL or FDP and it could connect these two muscles. This variation may lead to misinterpretation of LCV presence. Presence of pain or discomfort noted in some subjects during active thumb flexion but without any involuntary movement also limits our results because of undetected etiology.

Conclusion

The results of our study demonstrated a relatively high prevalence of the Linburg–Comstock variation in Serbian population. In general population, bilateral prevalence was significantly more common than unilateral prevalence while unilateral prevalence was more pronounced on left

side. Bilateral prevalence was significantly more common in females. Right-sided prevalence was more frequent in males while left-sided prevalence was frequently seen in females but the difference between them was not statistically significant. Although, all long fingers could be involved, the index finger was most often involved. Due to the possibility of false-positive result during clinical testing we suggest to use expanded clinical method.

Author contributions ME was involved in project and protocol development, data collection and management, data analysis, manuscript writing and editing; KY was involved in data management and analysis, manuscript writing and editing; VG was involved in data collection and manuscript editing; GF and DM were involved in manuscript writing and editing.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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