Assessment of the presence of independent flexor digitorum superficialis function in the small fingers of professional string players: Is this an example of natural selection?

Y. Godwin, G. A. C. Wheble and C. Feig

J Hand Surg Eur Vol published online 29 January 2013
DOI: 10.1177/1753193412474151

Full length article

JHS(E)

The Journal of Hand Surgery
(European Volume)
0E(0) 1–9

DOI: 10.1177/1753193412474151
jhs.sagepub.com
SAGE

Assessment of the presence of independent flexor digitorum superficialis function in the small fingers of professional string players: Is this an example of natural selection?

Y. Godwin, G. A. C. Wheble and C. Feig
Mountbatten Department of Plastic Surgery, Queen Alexandra Hospital, Portsmouth, UK

Abstract
This study estimated the prevalence of independent flexor digitorum superficialis function in the small fingers of 90 violin and viola players. The hypothesis tested was that the independent digital movements required in this population would select out those with absent flexor digitorum superficialis function. Professional string players were tested clinically, using standard and modified tests, for flexor digitorum superficialis function. Two additional physical tests were applied: the gap and stretch tests. These tests assess ring finger movement once the small finger is placed and the instrument is held in the chin-hold position. A statistically significant reduction in the prevalence of absent flexor digitorum superficialis function was confirmed in the musicians compared with a control group and published meta-analysis. This suggests that independent flexor digitorum superficialis function is important for professional musicians playing at an elite level.

Keywords
Flexor digitorum superficialis function, small finger, violin players, viola players

Date received: 21st May 2012; revised: 16th December 2012; accepted: 17th December 2012

Introduction

The anatomical variations of the flexor digitorum superficialis (FDS) to the small finger are well known. The tendon may be absent (Furnas, 1965) or hypoplastic (Baker et al., 1981), or may rely on inter-tendinous links with the FDS of the ring finger to obtain flexion (Kaplan, 1969). Based on these anatomical variations, independent flexion of the proximal interphalangeal joint (PIPJ) of the small finger may be present or functionally inferior to its counterparts in other fingers (Baker et al., 1981). Individuals in whom the tendon is absent are totally reliant on the flexor digitorum profundus (FDP) for flexion at both interphalangeal joints of the small finger. FDP action results in flexion of both interphalangeal joints of a single finger. This is accompanied by a degree of mass movement of adjacent digits as the FDP tendons arise from a common muscle belly.

We wished to investigate whether lack of independent movement of the small finger PIPJ affected the musical ability of string players. Because an anatomical variation is fixed, training and strengthening exercises will be unlikely to correct any issues of technique that arise as a result. Professional orchestra violinists and viola players were examined for the absence of independent FDS function. Our hypothesis was that absence of FDS function could be sufficient to act as a form of natural selection against a professional musical career.

Methods

Ninety professional musicians were examined from three of London's leading orchestras. The cohort was divided into the standard orchestra subsets (first violinists, second violinists, and viola players), as technical demands may vary between them. Thirty-eight players were first violinists, 33 were second violinists,

Corresponding author:
Y Godwin, Flat 1 Celtic House, Hooper Street, Cambridge CB1 2PB
Email: ygodwin@hotmail.com

Table 1. Explanation of standard and modified FDS function tests, and implications on independent movement of the small finger PIPJ.

Standard test	
Demonstrates functional ability of FDS to independently flex the small finger PIPJ	
Result	**Conclusion**
Small finger flexes at PIPJ alone without DIPJ flexion in conjunction	PIPJ flexes actively and independently using FDS alone as a motor Individual has **independent FDS function**
No PIPJ flexion seen or only seen in conjunction with small finger DIPJ flexion (Figure 1)	Patient cannot perform PIPJ flexion in isolation. PIPJ flexion occurs only in conjunction with flexion of other joints and digits **FDS function is not independent** *Modified test is applied*
Modified test	
Demonstrates whether any small finger PIPJ flexion occurs in conjunction with ring finger flexion	
Results	**Conclusion**
Small finger PIPJ flexes with no DIPJ flexion (Figure 2)	FDS of the ring finger is linked to a weak, non-independent FDS tendon to the small finger that motors the PIPJ flexion Individual has **common FDS function**
No small finger PIPJ flexion seen or small finger PIPJ flexion seen, but only in conjunction with DIPJ flexion (Figure 3)	PIPJ flexion of the small finger is dependent of FDP. FDS is absent or non-functional Individual has **absent FDS function**
Summary	
Individuals considered to have **independent FDS function** have an FDS tendon present, enabling isolated, independent flexion of the small finger PIPJ	
Individuals with **common FDS function** have PIPJ flexion, but this is not an isolated movement by an independent FDS motor to the small finger	
Individuals with **absent FDS function** cannot perform isolated PIPJ joint flexion of the small finger	

and 19 were viola players. All the musicians have the following in common: a chin hold of the instrument and need to adduct the shoulder, along with maximal supination at the elbow, in order to position the hand and, hence, place the fingers accurately on the neck of the instrument.

The prevalence of absent FDS function amongst the musicians was compared with that in a control group. The control group was recruited from members of the general population who were of similar age and sex distribution as the musician population. There were no professional musicians in the control group. Ninety-one control candidates were asked to take part in the study and none declined to be examined. The prevalence of absent FDS function for the professional musicians was also compared with published prevalence assessments for the general population. Any musicians found to have absent FDS function were asked if they had needed to modify their technique during the course of their training.

The standard and modified tests (Table 1) were applied to assess independent FDS function of the small finger (Austin et al., 1989; Baker et al., 1981; Puhaindran et al., 2008; Stein et al., 1990). In the standard test, the hand was placed in supination and the wrist placed in neutral; index, middle, and ring fingers were held in full extension at the metacarpal phalangeal joint (MCPJ) and interphalangeal joints. This extension immobilizes the FDP to the small finger so that any active flexion of the PIPJ is from the action of the superficialis alone. Participants were asked to actively flex the small finger. Full flexion (80–100°) at the PIPJ corresponds to independent FDS action. Lack of PIPJ flexion (Figure 1) suggests absent or less than full independent FDS function.

The modified test was applied to any candidate who lacked independent PIPJ flexion in the standard test. The participant was asked to actively flex the small finger whilst the ring finger was liberated, but the middle and index fingers were held in extension. The observer noted whether any flexion at the small finger PIPJ was possible and recorded the category of FDS function (Puhaindran et al., 2008) (Table 1; Figures 2 and 3). The modified test does not clarify the anatomical mechanism behind the presence or absence of PIPJ flexion in the small finger; it merely demonstrates whether some degree of small finger

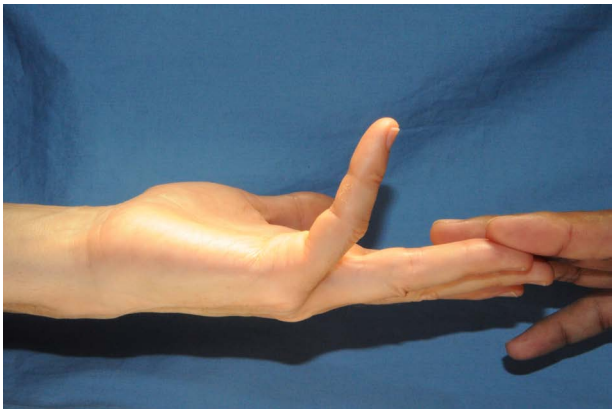

Figure 1. Standard test. Absent independent FDS function in the left small finger.

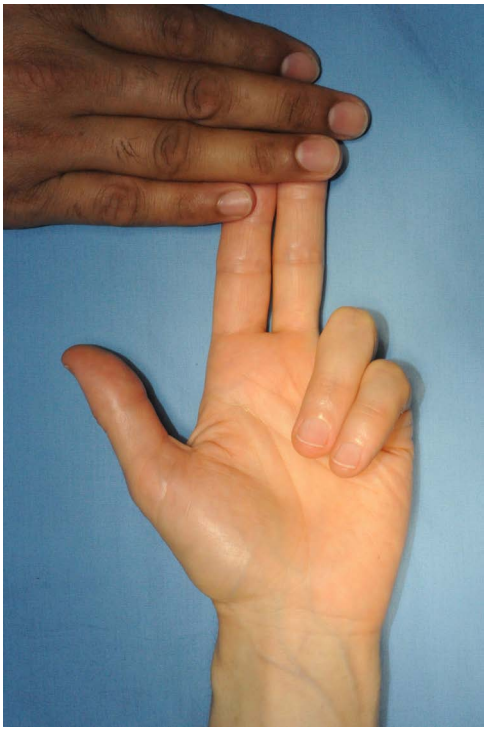

Figure 2. Common FDS function. Modified test shows isolated PIPJ flexion of the small finger if the ring finger is also flexed.

PIPJ flexion is possible once the ring finger is liberated.

From the above two tests, the musicians and control groups could be further divided into three groups. Their FDS function was graded as either independent, common, or absent. All musicians were asked to do the gap and stretch tests outlined in Table 2 and illustrated in Figures 4a–d and 5a–b. These tests are arbitrary and not classical musical exercises. They were designed so that the reviewer could measure problems

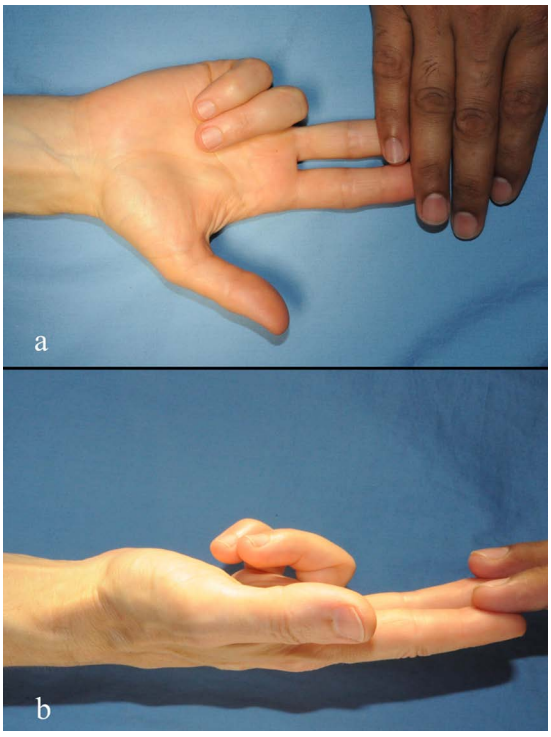

Figure 3. Absent FDS function. Isolated flexion of the PIPJ of the small finger is not possible. (a,b) Both the PIPJ and DIPJ of the small finger actively flex together on release of the ring finger.

arising from independent/non-independent movement of the ring finger once the small finger is in active flexion on the instrument neck. These tests were not applied to the control group of non-musicians.

The Chi-squared and Fisher's exact tests were used to test differences in the prevalence of absent FDS function between the musician group and non-musician control group, as well as published prevalence data (Townley et al., 2010). One-way analysis of variance, with a post-hoc Bonferroni multiple comparison test, was used to determine the statistical significance of any differences in the gap height and perceived difficulty of the stretch tests.

Results

Ninety string players were examined. Table 3 shows the demographics of the player subgroups and control group. All musicians bowed with the right hand and fingered with the left. The bowing hand is always the right within the orchestra, irrespective of hand dominance, due to the aesthetics and practical need for all bows to move in the same direction at the same time.

Nine hands in the musician cohort did not have independent FDS function. Of these, seven were recorded on the right bowing hand, and so were

Table 2. Summary of the gap and stretch tests.

Test	Measurement taken
Gap test	
Place index, middle, ring, and small finger on E string (*Figure 4a,b)	
Attempt to raise the ring finger off the E while leaving other fingers down (*Figure 4c,d)	Measure the clearance between E string and ring finger tip (mm)
Stretch test	
Place index, middle, ring, and small fingers on E string Ask player to reach over for G with the ring finger without raising the small finger from E (*Figure 5a)	Record • Any loss of DIPJ flexion in the ring finger? • Any loss of DIPJ flexion in the small finger? • Does the ring finger pulp touch the D string? • Does the small finger involuntarily move with the ring finger? (*Figure 5b)
General questions asked	
• Player scores from 1–10 the difficulty/effort involved to execute the stretch test (1 = with ease, 10 = most difficult) • Has the player perceived independent ring and small finger movement as a problem to overcome during training? • Any trick movements developed to compensate?	

*Illustrated in a participant with common FDS function in the left small finger.

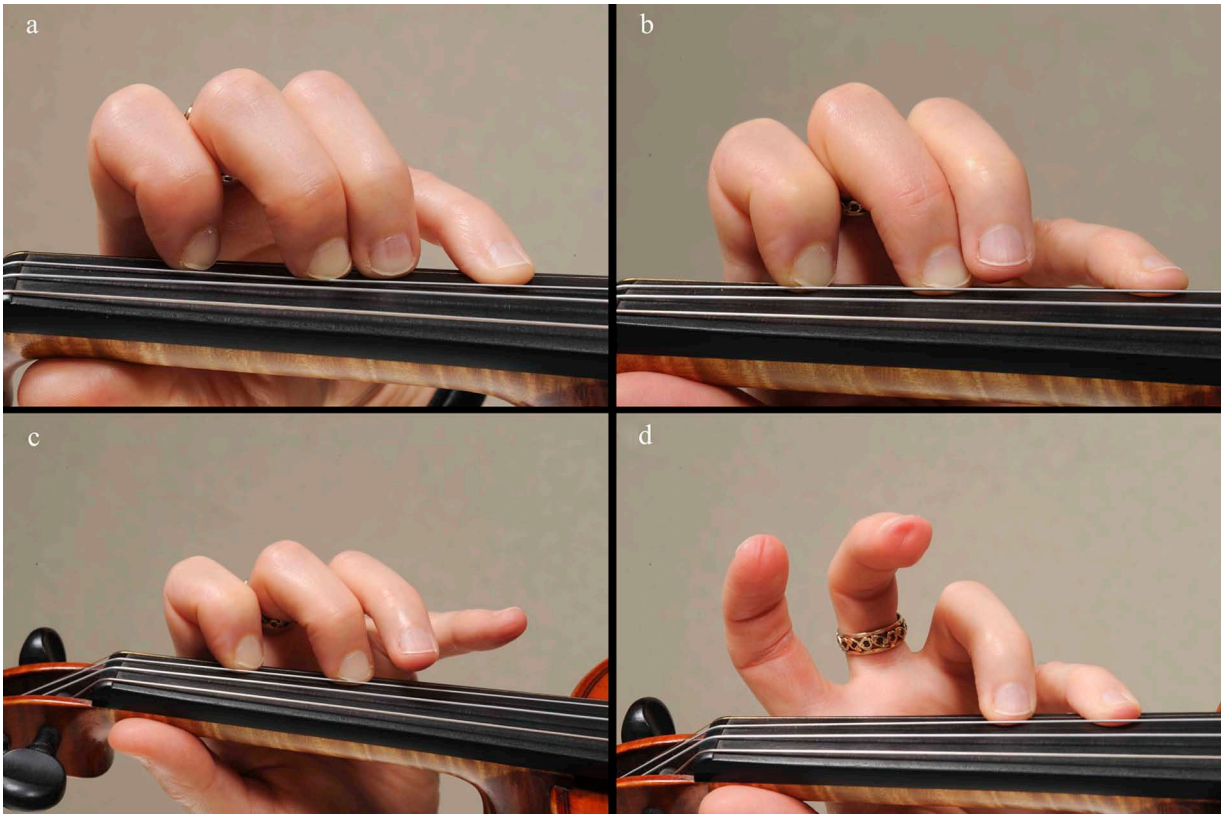

Figure 4. Gap test. The player has common FDS function in the left small finger. (a) Lateral view of violin neck with all digits flexed and aligned on E string. (b) Only minimal elevation of the ring finger is possible once the small finger is flexed to contact the string. (c) No further extension of the ring finger is possible unless the small finger is raised too. (d) Index and middle fingers are free to flex and extend independently, irrespective of the placement of ring and small finger.

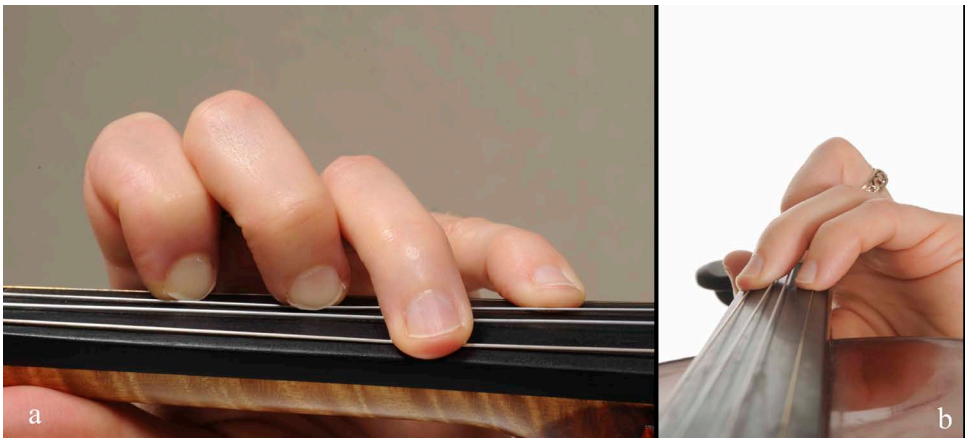

Figure 5. Stretch test. The player has common FDS function in left small finger. (a) When the small finger is kept in flexion on the E string, FDP strongly tethers the ring finger into flexion. Reaching over to the G string, whilst keeping the small finger down, results not only in discomfort but bad technique. The degree of DIPJ and PIPJ flexion involuntarily decreases for both digits. (b) The same position as viewed by the player down the neck of the violin. Even with maximum effort, along with elbow supination and shoulder adduction, the ring finger pulp does not clear the D string when reaching over to G.

Table 3. General demographic details of populations studied.

	Violin, First	Violin, Second	Viola	Control group
Average age (y)	46 (range 24–64)	40 (range 23–64)	47 (range 30–64)	40 (range 23–67)
% of group	42 (38/90)	37 (33/90)	21 (19/90)	100
Gender, %				
Female	42	60	53	46
Male	58	40	47	54
Hand dominance, %				
Right	92	94	89	88
Left	8	6	11	12
Fingering hand, %				
Right	0	0	0	N/A
Left	100	100	100	N/A

irrelevant to the hypothesis of the study, and two were recorded in the left hand. In the control group, 77 hands did not have independent FDS function (44 right hands, 33 left hands).

Table 4 summarizes the prevalence of the three types of FDS function. Ninety-eight percent (88/90) musicians showed independent FDS function in the left hand small fingers on the standard test. The two candidates who did not have independent FDS function were both first violinists. They both demonstrated common FDS function in the left small finger on the modified test. Hence, no string player showed total absence of FDS function in the left fingering hand. Three of the 90 musicians showed absent FDS function in the right bowing hand.

The prevalence of absent FDS function in the study control group was significantly higher than that of the musicians ($p < 0.0001$). The mean prevalence of absent FDS function quoted for the general population in the meta-analysis by Townley et al. (2010) was similarly significantly higher than within the musician group ($p = 0.0155$). In this study, absent FDS function was more common in the left hand of the control group compared with the musician population ($p = 0.0018$).

Table 5 summarizes the results of the gap and stretch tests applied to the musicians only. The average gap achieved by players with independent FDS function was 36 (range 8–93) mm, compared with an average 27 (range 17–37) mm for the two players with common function in the FDS. Statistical analysis of the gap difference between these groups was not appropriate because of the small number of candidates with common FDS function. Figure 6 illustrates the variability in gap height achieved by the player

Table 4. Prevalence of the three types of FDS function recorded in the small fingers of string players compared with a control group and published data.

Prevalence	String players 90 individuals	Control group 91 individuals	Townley et al., 2010 Meta-analysis of 1786 individuals
Independent FDS function			
Right hand	92% (83/90)	52% (47/91)	
Left hand	98% (88/90)	64% (58/91)	
Common FDS function			
Right hand	4.4% (4/90)	23% (21/91)	
Left hand	2.2% (2/90)	18% (16/91)	
Absent FDS function			
Right hand	3.3% (3/90)	25% (23/91)	Right and left not considered separately in study
	3.3%* (3/90)	12%* (11/90)	
	0.0%† (0/90)	13%† (12/90)	
Left hand	0% (0/90)	19% (17/91)	Absent FDS function: unilateral 6.8%, bilateral 6.0%
	0.0%* (0/90)	5.6%* (5/90)	
	0.0%† (0/90)	13%† (12/90)	
Overall prevalence of absent FDS function in each group	3.3% (3/90)	31% (28/91)	14% (SEM 3.7%) range 3.3%– 30%

*Unilateral prevalence of absent FDS function.
†Bilateral prevalence of absent FDS function.

Table 5. Recorded outcome of the gap and stretch tests applied to the left small and ring fingers of professional string players.

Test/question	Violin, First	Violin, Second	Viola
Gap test			
Mean gap between E string and ring finger tip (clearance) measured in mm	36 (range 12–93)	37 (range 9–66)	33 (range 8–60)
Stretch test			
Loss of ring finger DIPJ flexion	Nil	Nil	Nil
Loss of small finger DIPJ flexion	Nil	Nil	Nil
Ring finger pulp touches the adjacent D string	Nil	Nil	Nil
Small finger involuntarily moves with the ring finger	Nil	Nil	Nil
Player commented on stretch test difficulty	24% (9/38)	33% (11/33)	21% (4/19)
Response to questions asked			
Players' mean scores (from 1–10) of the difficulty involved in performing the stretch test	2.9 (range 1–9)	3.3 (range 1–8)	3.4 (range 1–7)
Players' need to train specifically to overcome non-independent small and ring finger flexion	Nil	Nil	Nil
Trick movements developed to compensate for non-independent digital movement	Nil	Nil	Nil

subgroups. No statistically significant difference was found between the group means ($p = 0.3297$).

Figure 7 illustrates the player's score for the difficulty they experienced during the stretch test within each subgroup. The overall difficulty of the stretch test for the whole orchestra was rated as 3.2 out of 10 (range 1–9). The average score for first violinists was 2.9 (range 1–9); second violinists, 3.3 (range 1–8); and violas, 3.4 (range 1–7). There was no perceived problem moving the ring finger when the small finger was in fixed flexion, irrespective of the player subgroup ($p = 0.6804$). For the two players with common FDS function, the average difficulty score was 5 (range 1–8). As there were only two candidates, statistical evaluation was not possible. Because none of the musicians demonstrated absent FDS function in the

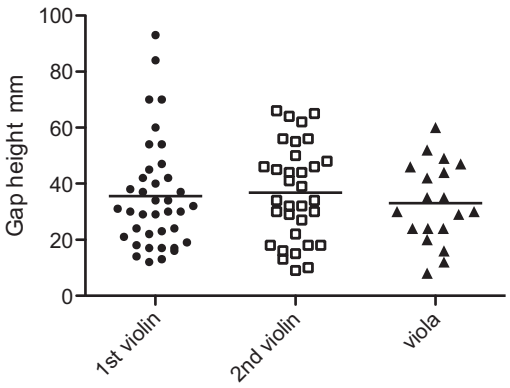

Figure 6. Gap test measurements within each musician subgroup.

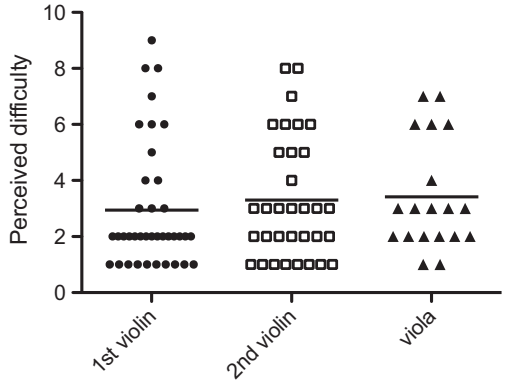

Figure 7. Difficulty score perceived to perform the stretch test within each musician subgroup (1 = minimum difficulty, 10 = maximum difficulty).

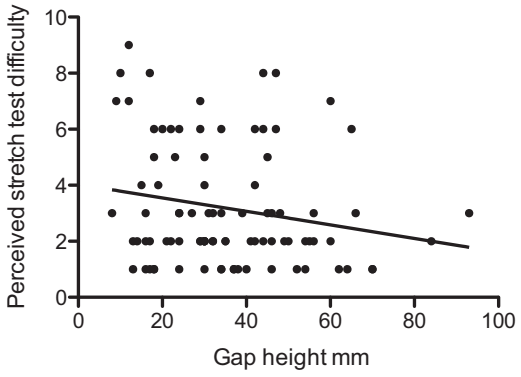

Figure 8. Difficulty score for the stretch test compared to height achieved in the gap test.

left small finger, no comment could be made as to whether this absence caused functional problems on playing.

During observation of the players executing the stretch test, there was no loss of DIPJ flexion either at the placed small finger or moving ring finger. There was no unnecessary contact of the ring finger pulp due to an inability to raise the moving ring finger above the string once the small finger was in fixed flexion. No player experienced involuntary movement of the small finger when the ring finger was extended across the neck of the instrument during the stretch test.

The gap and stretch tests were compared. Figure 8 shows a graph of gap test height plotted against perceived difficulty score for performing the stretch test. Pearson's correlation (r = –0.1957) suggested that there was no correlation between the height a musician could lift the ring finger and perceived difficulty in stretching the ring finger across the neck of the instrument.

All players were asked for general comments about the stretch test. Only 11 of the 24 players who rated the test difficult made a comment. Three felt they had difficulty in executing the test because of their hand size, three felt that they had to think harder than normal (i.e., the move did not come naturally), and five explained the move was just technically challenging. No player in any orchestra perceived problems in relation to executing independent motion between the index and small fingers. This included the player who had common FDS function and rated the stretch test as difficult.

All musicians were asked if they adopted any trick movements to improve independent small and ring finger placement. None of the 90 players interviewed had noticed a specific adjustment to their technique. The two players who had common function in the FDS equally did not report any need to compensate.

Discussion

This study was conceived after an 11-year-old patient volunteered that she had given up playing the violin because of difficulty and discomfort manoeuvring the left small and ring fingers independently. On examination, she was found to have absent FDS function in the small finger.

After the recorder, the violin is the instrument most commonly offered to children by state schools in the UK. The violin is a challenging instrument. Rapid, independent motion of the digital joints in the left hand is desirable. We hypothesized that absence of independent FDS function in the small finger might compromise the dexterity of the player, because the FDP would flex both small finger interphalangeal joints in unison and cause concurrent involuntary flexion of the ring finger by mass action. Once the small finger actively engages the string, the FDP

would tether the ring finger into flexion, acting as an antagonist to any active, voluntary, independent ring finger extension that the player might try to execute. This causes difficulty and discomfort, as our young patient indicated.

The prevalence of absent FDS function of the small finger is quoted as 13.7 % in the general population (Townley et al., 2010). The study found a statistically significant lower prevalence within the professional musicians (3.3%) and no examples of absent FDS function in their left hands. A lower prevalence of this anatomical variation amongst adults who excel in musical ability could be interpreted as a form of natural selection in the musical world.

We found no previous studies of anatomical and functional variations of FDS tendons in string musicians. The application of the standard test is used clinically to check if tendon function is absent after traumatic tendon laceration (Baker et al., 1981; Puhaindran et al., 2008; Stein et al., 1990; Townley et al., 2010). The standard test gives both functional and anatomical information concerning the FDS tendon. The modified test only demonstrates non-independent FDS function; it does not give any anatomical information about the structures involved in digital flexion (Puhaindran et al., 2008; Stein et al., 1990; Thompson et al., 2002; Townley et al., 2010). Common FDS function may result from an interconnection between the FDS of the ring and small fingers (Kaplan, 1969). Absent FDS function suggests that the FDS may be anatomically hypoplastic or totally absent.

The gap and stretch tests were originally devised for any musician found to have absent FDS function. Because only two candidates had less than fully independent FDS function, the test was applied to the whole group of musicians. Figures 4 and 5 illustrate the gap and stretch tests being carried out by a non-musician who has common FDS function. It demonstrates the problems that can arise during finger placement if the ring and small fingers cannot move with full independence. Although most of the musicians had independent FDS function, many of them described some difficulty with independent movements of ring and small fingers during their early training. This suggests that the mass action of the FDP does cause some limitation when very high musical standards are set. However, this improves with training, suggesting some relaxation of tethering elements within the FDP muscle unit.

We recognize the limitations of this study. Factors other than FDS function and the mass movement imparted by the FDP influence the independent movement of the small finger. The tendinous interconnections of the extensor apparatus can limit independent digital extension once adjacent digits are placed on the instrument neck. An ultra-sound scan, although operator dependent, could have improved this study by defining anatomical structures. FDS tendon hypoplasia or total absence could have been confirmed. The anatomical structures that flex the PIPJ in common FDS function could have been identified. The tendinous interconnections on the extensor surface of the hand could have been defined to determine whether they play a role in limiting movement. However, all the musicians were interviewed at their local rehearsal venues, so ultrasound analysis was not possible.

The study confirms that elite violinists and viola players usually have independent FDS function. Based on the outcome of this study, a recommendation could be made for children to be examined for FDS function before being offered the violin or viola as an instrument. Not having independent FDS function should not preclude a young player from taking up the violin, as not everyone needs to reach a professional level to get enjoyment from their playing. If a student is struggling, the standard test is easy to carry out. If absent FDS function is confirmed, an explanation about why certain movements are difficult to execute might be more helpful than giving the advice to practise more.

Acknowledgements

Our thanks to the three orchestras and musicians who shared their knowledge with us and allowed us to examine their hands: the London Symphony Orchestra, London Philharmonic Orchestra, and Orchestra of the Royal Opera House. Our thanks also to the Department of Medical Photography at Queen Alexandra Hospital Portsmouth, to Ajoy and Bijou of Guwahati Operation Smile Project in India, and Mr Sahan Rannan-Eliya for their help with the illustrations.

Conflict of interests

None declared.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sector.

Informed consent

Informed consent has been obtained from all musicians and control volunteers interviewed. Consent has been obtained for the illustrations included in this manuscript.

References

Austin GJ, Leslie BM, Ruby LK. Variations of the flexor digitorum superficialis of the small finger. J Hand Surg Am. 1989, 14: 262–7.

Baker DS, Gaul Jr JS, Williams VK, Graves M. The little finger superficialis — clinical investigation of its anatomic and functional shortcomings. J Hand Surg Am. 1981, 6: 374–8.

Furnas DW. Muscle-tendon variations in the flexor compartment of the wrist. Plast Reconstr Surg. 1965, 36: 320–4.

Kaplan EB. Muscle and tendinous variations of the flexor digitorum superficialis of the fifth finger of the hand. Bull Hosp Joint Dis. 1969, 30: 59–67.

Puhaindran ME, Sebastin SJ, Lim AYT, Xu WX, Chen YM. Absence of flexor digitorum superficialis tendon in the little finger is not associated with decreased grip strength. J Hand Surg Eur. 2008, 33: 205–7.

Stein A, Lemos M, Stein S. Clinical evaluation of the flexor tendon function in the small finger. Ann Emerg Med. 1990, 19: 991–3.

Thompson NW, Mockford BJ, Rasheed T, Herbert KJ. Functional absence of flexor digitorum superficialis to the little finger and absence of palmaris longus — is there a link? J Hand Surg Br. 2002, 27: 433–4.

Townley WA, Swan MC, Dunn RLR. Congenital absence of flexor digitorum superficialis: Implications for assessment of little finger lacerations. J Hand Surg Eur. 2010, 35: 417–8.