Pain assessment in children undergoing venipuncture: the Wong–Baker faces scale versus skin conductance fluctuations

Francesco Savino¹, Liliana Vagliano², Simone Ceratto¹, Fabio Viviani¹, Roberto Miniero³ and Fulvio Ricceri⁴

¹ Città della Salute e della Scienza di Torino, Regina Margherita Children’s Hospital, Dipartimento di Scienze della Sanità Pubblica e Pediatriche, University of Turin, Italy
² Experimental Pediatrics, Department of Pediatrics, Doctoral School in Biomedical Sciences and Human Oncology, University of Turin, Italy
³ Department of Internal Medicine and Surgery, Università della Magna Grecia, Catanzaro, Italy
⁴ Human Genetics Foundation, Turin, Italy

ABSTRACT

The aim of this study was to evaluate the efficacy of the subjective Wong–Baker faces pain rating scale (WBFS) and of the objective skin conductance fluctuation (SCF) test in assessing pain in children undergoing venipuncture. One-hundred and fifty children (aged 5–16 years) entered the study. All underwent venipuncture at the antecubital fossa to collect blood specimens for routine testing in the same environmental conditions. After venipuncture, the children indicated their pain intensity using the WBFS, whereas the number of SCFs was recorded before, during and after venipuncture. So, pain level was measured in each child with WBFS and SCF. We found that the level of WBFS-assessed pain was lower in all children, particularly those above 8 years of age, than SCF-assessed pain (p < 0.0001). Moreover, the number of SCFs was significantly higher during venipuncture than before or after venipuncture (p < 0.0001). At multivariate regression analysis, age and previous experience of venipuncture influenced the WBFS (β = −1.81, p < 0.001, and β = −0.86, p < 0.001, respectively) but not SCFs. In conclusion, although both procedures can be useful for research and clinical practice, our findings show that WBFS was affected by age and previous venipuncture, whereas SCF produced uniform data. If verified in other studies, our results should be taken into account when using these tools to evaluate pain in children.

INTRODUCTION

During the routine care of children, painful invasive procedures such as venipuncture for the withdrawal of blood for hematological testing are usually inevitable in healthy and sick subjects. The importance of pain assessment and pain management is widely acknowledged (Drendel, Kelly & Ali, 2011), and alleviation of pain caused by minor invasive procedures in children is an important issue for humane reasons and in terms

How to cite this article Savino et al. (2013), Pain assessment in children undergoing venipuncture: the Wong–Baker faces scale versus skin conductance fluctuations. PeerJ 1:e37. DOI 10.7717/peerj.37
of their reactions to future painful events and acceptance of subsequent health care interventions; (von Baeyer et al., 2004) moreover, unrecognized pain can become severe and difficult to control and lead to fear and stress (Roeggen, 2009).

Pain assessment is an ongoing and integral part of total pain management particularly in children, and includes such approaches as distraction, evaluation, reassessment and medical intervention (Davidson & McKenzie, 2011; Eichenfield et al., 2002; Mathew & Mathew, 2003; Taddio et al., 2011). Children and adolescents often describe invasive procedures and their associated anticipatory anxiety as the most distressing aspect of illness or hospitalization (von Baeyer et al., 2004). Venipuncture is one of the most feared and acute painful experience in children (McMurtry et al., 2011).

The main difficulty in assessing pain in children is the potential discrepancy between the perception and experience of pain and its expression (Alexander et al., 1993; Davidson & McKenzie, 2011; Eichenfield et al., 2002; Mathew & Mathew, 2003; Roeggen, 2009; Taddio et al., 2011; von Baeyer et al., 2004). Self-report faces scales are widely used to evaluate pain intensity in children despite concerns regarding interpretability (Stinson et al., 2006; Tomlinson et al., 2010). Most scales have five to seven faces, which are intended to elicit an indication of pain intensity (Beyer & Aradine, 1987; Hicks et al., 2001; Kuttner, 1989; LeBaron & Zeltzer, 1984; Wallin, Sundlof & Delius, 1975). This gives more information than a simple binary “pain”/“no pain” response.

Faces scales are frequently used as self report measures of pain intensity in research and clinical practice, and the Royal College of Nursing has identified the WBFS as suitable for peri-procedural pain (Roeggen, 2009).

Various pain assessment tools have been tested in the search for objective, specific physiologic measures of responses to pain in infants (Stapelkamp et al., 2011). One of the most investigated is skin conductance fluctuations (SCF) per sec measured in the palm of the hand or on the plantar aspect of the foot (Tranel & Damasio, 1994). Skin conductance fluctuations in these sites reflect emotional sweating due to skin sympathetic nerve activity. They occur within 1–2 s of the onset of emotional stressors such as pain (Hagbarth et al., 1972; Wallin, 1978). Because SCF are induced by acetylcholine acting on muscarinic receptors, they are not affected by environmental temperature, hemodynamic changes or respiratory rhythm medications such as beta blockers and neuromuscular blockers (Bini et al., 1980; Macefield & Wallin, 1996; Wallin, 1978). Furthermore, changes in respiratory rhythm (including apnea) do not influence SCF (Habler et al., 1993; Hanada, Sander & Gonzalez-Alonso, 2003; Valkenburg et al., 2012). Thus, changes in skin conductance are considered useful to monitor nociceptive stimulation and pain (Storm, 2008). The test has also been used to identify increased emotional stress as reflected in changes in the sympathetic nervous system as a measure of discomfort in artificially ventilated children (Gjerstad et al., 2008) and in other conditions (Eriksson et al., 2008; Harrison et al., 2006; Hellerud & Storm, 2002; Ledowski et al., 2006; Munsters et al., 2012; Roeggen, Storm & Harrison, 2011; Storm et al., 2002; Storm et al., 2005). However, also such sympathetic nerve activity as skin temperature autoregulation cause skin conductance peaks that are generally observed in pain states (Valkenburg et al., 2012).
Many pain management studies have focused on postoperative and chronic pain (Goddard, 2011; Lewandowski et al., 2010). However, although the simple insertion of a needle is one of the most frightening and distressing medical procedures for hospitalized children (Alexander et al., 1993; von Baeyer et al., 2004) the recognition and assessment of acute pain resulting from this procedure in children remains inadequate (Drendel, Kelly & Ali, 2011). We have evaluated simultaneously the efficacy of the Wong–Baker Faces Pain Rating Scale (WBFS), which is routinely used in our hospital and SCF per sec in measuring pain in children at different ages (with and without previous exposure to venipuncture), before, during and after venipuncture performed at the same anatomic location (antecubital fossa) (Wong & Baker, 1988).

METHODS

Study design
This was a prospective, observational study designed to explore relationships and differences between the WBFS to and the SCF during venipuncture in children 5–16 years old.

Patients
This analytical, observational study was undertaken in the Day Hospital of the Pediatric Specialist and Laboratory Analysis Service of the Children Hospital “Regina Margherita” (Turin, Italy). It was conducted between March 2010 and March (inclusive) 2011 and in accordance with good clinical practice and the Declaration of Helsinki. The protocol was approved by the Ethics Committee of the Azienda Ospedaliera, OIRM S. Anna – Ospedale Mauriziano (Turin, Italy).

We know that WBFS and SCF values are hardly to compare, but we decided to use a conversion table provided by the developer of SCF tool which made possible to convert the SCF values in a graded scale from zero to ten similar to WBFS grades.

A convenience sample of pediatric patients (5–16 years old) was enrolled: eligible patients were children or adolescents candidates for venipuncture for the collection of diagnostic blood specimens for routine hematological testing. All the patients were recruited at the “Regina Margherita” Children Hospital: some were recruited in the outpatient clinic and others were enrolled in Day Hospital, where they were followed for previous gastrointestinal diseases, endocrine disorders or diabetes mellitus type I. Children with known cognitive impairments, developmental delays, sensory deficits, pathological conditions of the palm and children receiving analgesic drugs were excluded from the study. Written consent was obtained from the parents, and verbal assent was obtained from each child or adolescent, adequately informed about the purpose of the study and the tools used. Parents were informed that their acceptance or refusal of the study would not affect clinical service. Basic demographic data (age, gender, previous diseases) were recorded. All the eligible children had to be subjected to venipuncture according to a previous clinical prescriptions in order to obtain diagnostic information.

All the venipunctures for the collection of blood were performed in the same setting with the same environmental temperature and by the same person. In our hospital
nonpharmacologic distraction techniques are routinely performed: for venipuncture all the subjects received parental holding and positioning.

**PAIN EVALUATION TOOLS**

**Wong–Baker faces scale**

The WBFS combines pictures and numbers to enable the user to rate pain (Fig. 1). It can be used for children over the age of 3, and for adults. The faces range from a smiling face to a sad, crying face. A numerical rating is assigned to each face (from 0, “no hurt” to 10, “hurts worst”) of the WBFS (Drendel, Kelly & Ali, 2011; Garra et al., 2010; Hicks et al., 2001; Kuttner, 1989; Stapelkamp et al., 2011; Stinson et al., 2006; Tomlinson et al., 2010).

The WBFS also has adequate psychometric properties (reliability, validity), and it is easy and quick to. The greatest strength of this scale may be its acceptability, given the consistent finding that the WBFS was preferred by children (any age), parents, and practitioners when compared with other faces pain scales (Tomlinson et al., 2010).

Concerning validity, WBFS has an high correlation ($r > 0.7$) with other self-reported pain scale used at the same time and shows differences ($p < 0.05$) in score between two comparable but different groups. Reliability has been proved by the use of “test and retest” ($r > 0.5$) and by the concordance with simultaneous observational score ($r > 0.4$). WBFS has a significant ($p < 0.05$) responsiveness to pain-increasing (painful procedures) and pain-decreasing (analgesia) events (Tomlinson et al., 2010).

**Skin conductance test. Instruments**

Skin conductance fluctuations were measured by alternating current at 88 Hz. Low-frequency electrical conductance reflects the ionic conduction in the stratum corneum, which is largely determined by sweat duct filling. Resistance and conductance are two related quantities in measuring voltage changes in skin conductance. Siemens is the unit of electrical conductance in the same way as Ohm is the unit of electrical resistance (Storm, 2008). Conductance was preferred to resistance because of the parallel nature of the electrical polarization and conductance in the skin. A frequency of 88 Hz is sufficient to reduce considerably the requirements for low electrode polarizability but also low enough to ensure minimal influence from layers other than the stratum corneum. In this study we
applied a voltage of 50 mV and used a 3-electrode system. The 3-electrode system consisted of a measuring electrode (M), a countercurrent electrode (C), and a reference voltage electrode (R), which ensured a constant applied voltage across the stratum corneum beneath the M electrode. The placement of the electrodes on enrolled children was on the palm of the hand according to the Fig. 2.

The distance between each electrode has been at least 7 mm as recommended by the manufacturer. The electrode named M was placed at the hypothenar emminence because this area on the palm gives highest stability and thus less movement artifacts; the electrode named R was placed below the third finger and the electrode named C was placed on the hypertenar side of the hand.

We used the Med-Storm software version 1.0.0.33 (Med-Storm Innovation AS, Oslo, Norway). The Med-Storm manual contains an index where the SC fluctuations per sec are transformed to a graded score from zero to ten (Fig. 3) [available at www.med-storm.com/]. This transformation is empirical and based, among other things, on pain referred by adults (Ledowski et al., 2007); similar results have been reported for children: sensitivity in 5–7 years old children is 97.0% while specificity is 72.9%; sensitivity in 8–16 years old subjects is 85.2% while specificity is 67.1% (Hullett et al., 2009).
Pain evaluation procedure with the WBFS and the skin conductance test

The WBFS was applied in the first minute after venipuncture; at that time, the children were asked to indicate on the picture (see Fig. 1) the level of pain they felt throughout the entire procedure. In the case of the SCT, electrodes were distributed over the palm of the hand. We divided the process of the measurement into three steps: preparation of the child; insertion of the needle; extraction of the needle. Skin conduction fluctuations per second were recorded at the same anatomic location, namely the antecubital fossa (see Fig. 2), and by the same operator (VM) using the BD Vacutainer 367286 blood collection set (21 G × 3/4” × 12” [0.8 × 19 mm × 305 mm]; Becton Dickinson & Company, Plymouth, UK). SCF was measured in each subject during venipuncture at least 10 min. They were recorded for 1 min before preparation of the child, during insertion of the needle, and for 1 min after extraction of the needle (Storm, 2008). Children and parents provided consent to the procedure, and nurses carried out the distraction techniques routinely used in our children’s hospital.

STATISTICAL ANALYSIS

The sample size was calculated to find a relationship in the evaluation of pain using the two methods, with an estimated correlation coefficient (based on a pilot study) of 0.175, \( \alpha = 0.05 \) and \( \beta = 0.55 \), 143 patients were needed per group.

We tested the normality of the two variables (WBFS and SCF) using the Kolmogorov-Smirnov test. Because of the rejection of normality assumption, we report data as median and interquartile range and we performed non parametric tests. We used the Wilcoxon signed rank test and the Spearman correlation coefficient to compare the scores obtained with WBFS and SCF. We also compared the scores of children with or without previous exposure to venipuncture and children at different ages using the Wilcoxon sum rank test. To determine the relevance of the studied variables in relation to pain, we performed a multivariate linear regression model. Statistical analyses were performed by using SAS 9.2 (SAS Institute Inc., Cary, NC, USA).
Table 1 Characteristics of the 150 children enrolled in the study.

| Age               | Mean years | SD  | Median year | Interquartile range (25th–75th) |
|-------------------|------------|-----|-------------|---------------------------------|
| Mean age (year)   | 10.49      | 0.36| 11.00       | 7–13                            |
| Gender            |            |     |             |                                 |
| Boys              |            |     |             |                                 |
| Girls             |            |     |             |                                 |
| Exposure to venipuncture |     |     |             |                                 |
| Never exposed     | 72 (48%)   |     | 100 (66.7%) |                                 |
| Previously exposed| 78 (52%)   |     | 50 (33.3%)  |                                 |

Table 2 Skin conductance values in relation to health status before venipuncture, during insertion of the needle and during removal of the needle.

|                                | Before venipuncture | Insertion of needle | Removal of needle | $P$   |
|--------------------------------|---------------------|---------------------|------------------|-------|
| All children (150)             | 0.27 (0.20–0.33)    | 0.33 (0.27–0.40)    | 0.20 (0.13–0.27) | <0.0001 |
| Never exposed (100)            | 0.20 (0.13–0.27)    | 0.40 (0.33–0.53)    | 0.17 (0.07–0.27) | <0.0001 |
| Exposed (50)                   | 0.27 (0.20–0.33)    | 0.33 (0.27–0.40)    | 0.22 (0.17–0.27) | <0.0001 |

Notes.
Unit of measurement: Peak per second of Siemens

RESULTS

Of the 195 patients assessed for eligibility, 150 children (78 girls and 72 boys) aged from 5 to 16 years were included in the study: 23 children did not meet the inclusion criteria, and 22 declined to participate in the study. One hundred children were undergoing venipuncture for routine hematologic tests for the first time (“never exposed”), while 50, who were affected by a chronic disease, had previously undergone venipuncture (see Table 1).

Table 2 shows the number of SCF 1 min before venipuncture, and during insertion and removal of the needle. Mean duration of procedures was 5.5 min (DS ± 1.2). The number of SCF per sec was significantly higher during venipuncture (0.33 fluctuations/s) than before venipuncture and during removal of the needle ($p < 0.0001$).

Table 3 shows the WBFS and SCF results. The self-report pain score was significantly lower than the SCF score (median WBFS score: 2; median SCF score: 5, $p < 0.0001$). This difference was consistent among all subgroups except for the younger children previously exposed to venipuncture, in whom the results of WBFS were consistent with the results of SCF (median score of 6 versus 6, $p 0.27$). Skin conductance fluctuations per sec were similar across all subgroups. Differently, in children below the age of 8 years, pain evaluated with the WBFS was less intense in those never exposed to venipuncture versus those with previous exposure (median of 2 versus 6, $p 0.0001$). Correlation analyses confirmed these
Table 3  Wong-Baker Faces Scale score and skin conductance per sec scores according to previous exposure to venipuncture and age.

| Status                        | Wong-Baker scale median (range) | Estimated pain scores (0–10) based on SC fluctuation median (range) | p-value |
|-------------------------------|---------------------------------|-----------------------------------------------------------------------|---------|
| All children (150)            | 2 (0–4)                         | 5 (4–6)                                                               | <0.0001 |
| Status                        |                                 |                                                                       |         |
| Never exposed to venipuncture (100) | 2 (0–4)                         | 5 (4–6)                                                               | <0.0001 |
| Previously exposed to venipuncture (50) | 2 (2–6)                         | 5 (4–6)                                                               | 0.04    |
| p-values                      | 0.004                           | 0.86                                                                  |         |
| Age                           |                                 |                                                                       |         |
| <8 years old (52)             | 4 (2–5)                         | 6 (4–6)                                                               | 0.002   |
| 8+ years old (98)             | 2 (0–4)                         | 5 (4–6)                                                               | <0.0001 |
| p-values                      | 0.0001                          | 0.30                                                                  |         |
| Sex                           |                                 |                                                                       |         |
| Male (72)                     | 2 (1–4)                         | 6 (4–6)                                                               | <0.0001 |
| Female (78)                   | 2 (0–4)                         | 5 (4–6)                                                               | <0.0001 |
| p-values                      | 0.19                            | 0.13                                                                  |         |
| <8 years old                  |                                 |                                                                       |         |
| Never exposed to venipuncture (37) | 2 (2–4)                         | 6 (4–6)                                                               | <0.0001 |
| Previously exposed to venipuncture (15) | 6 (4–10)                     | 6 (4–8)                                                               | 0.27    |
| p-values                      | 0.0001                          | 0.89                                                                  |         |
| 8+ years old                  |                                 |                                                                       |         |
| Never exposed to venipuncture (63) | 2 (0–4)                         | 5 (4–6)                                                               | <0.0001 |
| Previously exposed to venipuncture (35) | 2 (0–4)                         | 5 (4–6)                                                               | 0.0005  |
| p-values                      | 0.14                            | 0.83                                                                  |         |

Notes.
Method of comparison used: Wilcoxon test (p < 0.0001).

Table 4  Spearman correlation coefficient (p-value) between WBFS score and SC per sec score.

|                     | Spearman coefficient (p-value) |
|---------------------|-------------------------------|
| All subjects        | 0.30 (0.0002)                 |
| No previous experience of venipuncture | 0.28 (0.05)             |
| Previous experience of venipuncture   | 0.35 (0.0004)             |
| Children <8 years old | 0.35 (0.0004)             |
| Children >8 years old   | 0.20 (0.15)               |

results: WBFS scores are lowly correlated with SCF scores in older children and in children without previous experience of venipuncture (Table 4).

The results of the linear regression model (Table 5) show that age and previous exposure are important determinants of WBFS. In fact, the score was 1.81 points lower in older than in young children, and 0.86 points lower in children never exposed than in exposed children (both statistically significant, p < 0.0001). The $r^2$ of the model is 0.23, which
Table 5  Multivariate linear regression for the Wong–Baker Faces Scale scores and skin conductance fluctuations per sec scores.

| Dependent variable = Wong–Baker faces scale | β     | p-value | \( r^2 \) of the model |
|--------------------------------------------|-------|---------|-------------------------|
| Age                                        | -1.81 | <0.0001 |                         |
| Previous experience of venipuncture        | -0.86 | <0.0001 |                         |
| Sex                                        | 0.65  | 0.07    | 0.23                    |
| Dependent variable = Skin conductance      |       |         |                         |
| Age                                        | -0.42 | 0.26    |                         |
| Previous experience of venipuncture        | -0.09 | 0.65    |                         |
| Sex                                        | -0.39 | 0.27    | 0.000001                |

shows that age and health status are involved in WBFS pain assessment by children. On the contrary, neither age nor health status affected the SCF score (the \( r^2 \) approaches zero). Sex does not seem to affect either scale.

DISCUSSION

Painful invasive procedures such as venipuncture are usually inevitable during the routine care of children whether healthy or sick. Pediatric pain experiences are a consequence of an intricate interplay of genetic, experiential, and developmental factors (Walco, 2008). Therefore, pain assessment should not be an isolated element, but an ongoing and integral part of total pain management particularly in children (Taddio et al., 2011). Face scales are frequently used as self-report measures of pain intensity in research and clinical practice, and the Royal College of Nursing has identified the WBFS as suitable for peri-procedural pain (Roeggen, 2009; Tomlinson et al., 2010). Of the various objective pain assessment tools, one of the most widely investigated procedures is SCF per sec. In this study, we assessed the pain perceived by children during venipuncture using the two tools simultaneously: the WBFS (as subjective scale) and SCF per sec (as objective scale). The same stimulus, insertion of a needle, was used for children of different ages with and without previous exposure to venipuncture. Since the stimulus was the same for all children enrolled in the study, it was expected that the responses would be similar for the two methods and across all patient groups. To our knowledge, this is the first study to evaluate the WBFS and the SCF test simultaneously, and the first to use SCF to measure pain during venipuncture.

We found that SCF per sec were significantly higher during venipuncture than before the procedure. Therefore, the increase in the number of SCF per sec can be interpreted as a response to a painful procedure related to the insertion of the needle, whereas the SCF per sec recorded before beginning insertion of the needle are related to emotional stress and fear perceived by children (Pereira-da-Silva et al., 2012). In addition, we found that the increase in SCF per sec was not influenced by age or previous experience of venipuncture. Similarly, in previous studies conducted in infants, health status, gestational age and postnatal age did not affect SCF per sec during painful procedures or when the infant...
was calm (Munsters et al., 2012; Pereira-da-Silva et al., 2012; Roeggen, Storm & Harrison, 2011; Storm et al., 2002). Furthermore, using skin conductance monitoring, Roeggen et al. reported a very low variation between and within infants on the same discomfort level (behavioral state 1) (Roeggen, Storm & Harrison, 2011).

On the contrary, we found that the WBFS was affected by both age and previous experience of venipuncture although the correlation between the two methods is only low. In fact, the WBFS results differed between children below the age of 8 years with experience of venipuncture and older, venipuncture-naive children. This seems to be in line with the report by von Baeyer et al. that previous painful events play a role in the anticipation and evaluation of future pain experience (von Baeyer et al., 2004). In the older, never-exposed children, the lower values of WBFS with respect to SCF probably reflect an underestimation of pain related to a lack of sensitization, together with good practice of the team nurse and a comfortable environment during the procedure (von Baeyer et al., 2004). However, we cannot exclude that the distraction techniques used during application of the electrodes in the SCF test could have affected the children’s pain scores.

Pagé et al. used various pain scales to assess acute postoperative pain in children and observed that children aged 8–18 years find the faces scales the easiest to use (Pagé et al., 2012). Moreover, in a comparative prospective evaluation of responsiveness to self-report scales, Connelly et al. reported that patients tended to rate pain intensity higher with numerical rating scale than with a visual analog scale (Connelly & Neville, 2010).

A recent systematic review of cross-cultural comparison studies of child, parent, and health professional outcomes associated with pediatric medical procedures revealed that cultural factors may be associated with children’s pain experiences when elicited by medical procedural pain, specifically children’s pain behavior, but the authors noted that research using more sophisticated research methods is needed to develop culturally sensitive behavioral pain measures (Kristjansdottir et al., 2012). In this context, Drendel et al. reported that a variety of factors could affect the self-report of pain in children, and that optimizing the use of pain assessment remains a challenge for the health care provider in the emergency setting of pediatric practice (Drendel, Kelly & Ali, 2011).

Our findings using skin conductance monitoring are in line with those reported by Hullet et al. (Hullett et al., 2009) who monitored postoperative pain using a postoperative pain score in children. In fact, they found that the best accordance between a self-reported pain score and SCF per sec occurred in children between the ages of 4 and 8 years. Interestingly, two studies of postoperative pain in children showed that anxiety did not affect the skin conductance analysis (Choo et al., 2010; Hullet et al., 2009) and in one of the studies there was no correlation between skin conductance activity and WBFS scores (Choo et al., 2010), unlike our findings. The lack of correlation between the two procedures may be due to the low specificity of skin conductance to identify moderate pain or it could indicate that WBFS pain scores are influenced by age and health status as shown in our study.

A potential limitation of this study is the lack of previous scientific literature about the comparison between SCF and WBFS and this issue makes more difficult to establish the study design. Another limitation is the difficulty to convert SCF data in a numerical scale.
that could be compared with WBFS scores. Additionally there is no universally accepted lower age limit for the self-reporting of pain in the use of WBFS (Hicks et al., 2001). Further, fear and anxiety may bias pain reporting and interfere with attempts at measuring pain intensity; although the WBFS are reported to have content validity (Garra et al., 2010).

Lastly our sample size calculation is probably not adequate to examine the sub group analysis (previously exposed to venipuncture versus not).

In conclusion, this simultaneous evaluation of the WBFS and SCF in the assessment of pain in children undergoing a routine medical procedure showed that, although both tools can be useful for research and in clinical practice, SCF produced uniform data, whereas the WBFS was affected by age and previous venipuncture experience thereby providing new data about school-age children. If verified in other studies, our results should be taken into account when using these tools to evaluate pain in children and for providing more adequate pain care routine. Additional researches on positioning and of nonpharmacologic and pharmacologic interventions are needed, including larger samples sizes and expanded ages.

**Abbreviations**

SCF      Skin conductance fluctuations  
WBFS     Wong–Baker faces pain rating scale

**ACKNOWLEDGEMENTS**

The study was performed at the Day Hospital of the Pediatric Specialist and Laboratory Analysis Service of Children Hospital “Regina Margherita” of Turin, Italy. We thank the parents and the children who took part in this study and Valentina Marmora, MD who performed SC analysis.

We are grateful to the nurses in the Day Hospital and Outpatients Clinic who made the study possible. We also thank Ing P. Duva and Ing C. Marconi for their time and technical support.

Lastly, we are indebted to Jean Ann Gilder (Scientific Communication srl) for editing the text.

**ADDITIONAL INFORMATION AND DECLARATIONS**

**Funding**

This study was supported by a Research Grant from the Lions’ Club Torino Crimea Italy, the Ministero dell’Università e della Ricerca Scientifica e Tecnologica and the University of Turin 2007. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

**Grant Disclosures**

The following grant information was disclosed by the authors:  
Lions’ Club Torino Crimea Italy.
The Ministero dell’Università e della Ricerca Scientifica e Tecnologica.
University of Turin 2007.

Competing Interests
Francesco Savino is an Academic Editor for PeerJ. Otherwise, the authors declare no Conflicts of Interests.

Author Contributions
• Francesco Savino conceived and designed the experiments, wrote the paper.
• Liliana Vagliano performed the experiments, wrote the paper.
• Simone Ceratto contributed reagents/materials/analysis tools, wrote the paper.
• Fabio Viviani performed the experiments.
• Roberto Miniero contributed reagents/materials/analysis tools.
• Fulvio Ricceri analyzed the data.

Human Ethics
The following information was supplied relating to ethical approvals (i.e. approving body and any reference numbers):
Ethics Committee of the Azienda Ospedaliera, OIRM S. Anna – Ospedale Mauriziano (Turin, Italy).

REFERENCES
Alexander M, Richtsmeier AJ, Broome ME, Barkin R. 1993. A multidisciplinary approach to pediatric pain: an empirical analysis. Child Health Care 22(2):81–91 DOI 10.1207/si5326888chc2202_1.

Beyer J, Aradine C. 1987. Patterns of pediatric pain intensity: a methodological investigation of a self-report scale. Clinic Journal of Pain 3(3):130–141 DOI 10.1097/00002508-19870300-00003.

Bini G, Hagbarth KE, Hynninen P, Wallin BG. 1980. Thermoregulatory and rhythm-generating mechanisms governing the sudomotor and vasoconstrictor outflow in human cutaneous nerves. Journal of Physiology 306:537–552.

Choo EK, Magruder W, Montgomery CJ, Lim J, Brant R, Ansermino JM. 2010. Skin conductance fluctuations correlate poorly with postoperative self-report pain measures in school-aged children. Anesthesiology 113(1):175–182 DOI 10.1097/ALN.0b013e3181de6ce9.

Connelly M, Neville K. 2010. Comparative prospective evaluation of the responsiveness of single-item pediatric pain-intensity self-report scales and their uniqueness from negative affect in a hospital setting. Journal of Pain 11(12):1451–1460 DOI 10.1016/j.jpain.2010.04.011.

Davidson A, McKenzie I. 2011. Distress at induction: prevention and consequences. Current Opinion in Anaesthesiology 24(3):301–306 DOI 10.1097/ACO.0b013e3283466b27.

Drendel AL, Kelly BT, Ali S. 2011. Pain assessment for children: overcoming challenges and optimizing care. Pediatric Emergency Care 27(8):773–781 DOI 10.1097/PEC.0b013e31822877f7.

Eichenfield LF, Funk A, Fallon-Friedlander S, Cunningham BB. 2002. A clinical study to evaluate the efficacy of ELA-Max (4% liposomal lidocaine) as compared with eutectic mixture of local anesthetics cream for pain reduction of venipuncture in children. Pediatrics 109(6):1093–1099 DOI 10.1542/peds.109.6.1093.
Eriksson M, Storm H, Fremming A, Schollin J. 2008. Skin conductance compared to a combined behavioural and physiological pain measure in newborn infants. *Acta Paediatrica* 97(1):27–30 DOI 10.1111/j.1651-2227.2007.00586.x.

Garra G, Singer AJ, Taira BR, Chohan J, Cardoz H, Chisena E, Thode HC Jr. 2010. Validation of the Wong–Baker FACES Pain Rating Scale in pediatric emergency department patients. *Academic Emergency Medicine* 17(1):50–54 DOI 10.1111/j.1553-2712.2009.00620.x.

Gjerstad AC, Wagner K, Henrichsen T, Storm H. 2008. Skin conductance versus the modified COMFORT sedation score as a measure of discomfort in artificially ventilated children. *Pediatrics* 122(4):e848–853 DOI 10.1542/peds.2007-2545.

Goddard JM. 2011. Chronic pain in children and young people. *Current Opinion Support Palliative Care* 5(2):158–163 DOI 10.1097/SPC.O000328345832d.

Habler HJ, Janig W, Krummel M, Peters OA. 1993. Respiratory modulation of the activity in postganglionic neurons supplying skeletal muscle and skin of the rat hind limb. *Journal of Neurophysiology* 70(3):920–930.

Hagbarth KE, Hallin RG, Hongell A, Torebjork HE, Wallin BG. 1972. General characteristics of sympathetic activity in human skin nerves. *Acta Physiologica Scandinavica* 84(2):164–76 DOI 10.1113/jphysiol.1972.tb05167.x.

Hanada A, Sander M, Gonzalez-Alonso J. 2003. Human skeletal muscle sympathetic nerve activity, heart rate and limb haemodynamics with reduced blood oxygenation and exercise. *Journal of Physiology* 551(Pt 2):635–647 DOI 10.1113/jphysiol.2003.044024.

Harrison D, Boyce S, Loughnan P, Dargaville P, Storm H, Johnston L. 2006. Skin conductance as a measure of pain and stress in hospitalised infants. *Early Human Development* 82(9):603–608 DOI 10.1016/j.earlhumdev.2005.12.008.

Hellerud BC, Storm H. 2002. Skin conductance and behaviour during sensory stimulation of preterm and term infants. *Early Human Development* 70(1-2):35–46 DOI 10.1016/S0378-3782(02)00070-1.

Hicks CL, von Baeyer CL, Spafford PA, van Korlaar I, Goodenough B. 2001. The Faces Pain Scale-Revised: toward a common metric in pediatric pain measurement. *Pain* 93(2):173–183 DOI 10.1016/S0304-3959(01)00314-1.

Hulbett B, Chambers N, Preuss J, Zamudio I, Lange J, Pascoe E, Ledowski T. 2009. Monitoring electrical skin conductance: a tool for the assessment of postoperative pain in children? *Anesthesiology* 111(3):513–517 DOI 10.1097/ALN.0b013e3181b27c18.

Kristjansdottir O, Unruh AM, McAlpine L, McGrath PJ. 2012. A systematic review of cross-cultural comparison studies of child, parent, and health professional outcomes associated with pediatric medical procedures. *Journal of Pain* 13(3):207–219 DOI 10.1016/j.jpain.2011.12.008.

Kuttner L. 1989. Management of young children’s acute pain and anxiety during invasive medical procedures. *Pediatrician* 16(1–2):39–44.

LeBaron S, Zeltzer L. 1984. Assessment of acute pain and anxiety in children and adolescents by self-reports, observer reports, and a behavior checklist. *Journal of Consulting and Clinical Psychology* 52(5):729–738 DOI 10.1037/0022-006X.52.5.729.

Ledowski T, Bromilow J, Wu J, Paech MJ, Storm H, Schug SA. 2007. The assessment of postoperative pain by monitoring skin conductance: results of a prospective study. *Anaesthesia* 62(10):989–993 DOI 10.1111/j.1365-2044.2007.05191.x.

Ledowski T, Paech MJ, Storm H, Jones R, Schug SA. 2006. Skin conductance monitoring compared with bispectral index monitoring to assess emergence from general anaesthesia.
using sevoflurane and remifentanil. British Journal of Anaesthesia 97(2):187–191 DOI 10.1093/bja/ael119.

Lewandowski AS, Palermo TM, Stinson J, Handley S, Chambers CT. 2010. Systematic review of family functioning in families of children and adolescents with chronic pain. Journal of Pain 11(11):1027–1038 DOI 10.1016/j.jpain.2010.04.005.

Macefield VG, Wallin BG. 1996. The discharge behaviour of single sympathetic neurones supplying human sweat glands. Journal of Autonomic Nervous System 61(3):277–286 DOI 10.1016/S0165-1838(96)00095-1.

Mathew PJ, Mathew JL. 2003. Assessment and management of pain in infants. Postgraduate Medical Journal 79(934):438–443 DOI 10.1136/pgmj.79.934.438.

McMurtry CM, Noel M, Chambers CT, McGrath PJ. 2011. Children’s fear during procedural pain: preliminary investigation of the children’s fear scale. Health Psychology 30(6):780–788 DOI 10.1037/a0024817.

Munsters J, Wallstrom L, Agren J, Norsted T, Sindelar R. 2012. Skin conductance measurements as pain assessment in newborn infants born at 22–27 weeks gestational age at different postnatal age. Early Human Development 88(1):21–6 DOI 10.1016/j.earlhumdev.2011.06.010.

Pagé MG, Katz J, Stinson J, Isaac L, Martin-Pichora AL, Campbell F. 2012. Validation of the numerical rating scale for pain intensity unpleasantness in pediatric acute postoperative pain: sensitivity to change over time. Journal of Pain 13(4):359–369 DOI 10.1016/j.jpain.2011.12.010.

Pereira-da-Silva L, Virella D, Monteiro I, Gomes S, Rodrigues P, Serelha M, Storm H. 2012. Skin conductance indices discriminate nociceptive responses to acute stimuli from different heel prick procedures in infants. Journal of Maternal Fetal-Neonatal Medicine 25(6):796–801 DOI 10.3109/14767058.2011.587919.

Roeggen I, Storm H, Harrison D. 2011. Skin conductivity variability between and within hospitalised infants at rest. Early Human Development 87(1):37–42 DOI 10.1016/j.earlhumdev.2010.09.373.

Royal College of Nursing. The recognition and assessment of acute pain in children. Update of full guideline. London: The Royal College of Nursing. Clinical Practice Guidelines. 2009.

Stapelkamp C, Carter B, Gordon J, Watts C. 2011. Assessment of acute pain in children: development of evidence-based guidelines. International Journal of Evidence Based Health 9(1):39–50 DOI 10.1111/j.1744-1609.2010.00099.x.

Stinson JN, Kavanagh T, Yamada J, Gill N, Stevens B. 2006. Systematic review of the psychometric properties, interpretability and feasibility of self-report pain intensity measures for use in clinical trials in children and adolescents. Pain 125(1–2):143–157 DOI 10.1016/j.pain.2006.05.006.

Storm H. 2008. Changes in skin conductance as a tool to monitor nociceptive stimulation and pain. Current Opinion in Anaesthesiology 21(6):796–804 DOI 10.1097/ACO.0b013e3283183fe4.

Storm H, Myre K, Rostrup M, Stokland O, Lien MD, Raeder JC. 2002. Skin conductance correlates with perioperative stress. Acta Anaesthesiologica Scandinavica 46(7):887–895 DOI 10.1034/j.1399-6576.2002.460721.x.

Storm H, Shafiei M, Myre K, Raeder J. 2005. Palmar skin conductance compared to a developed stress score and to noxious and awakening stimuli on patients in anaesthesia. Acta Anaesthesiologica Scandinavica 49(6):798–803 DOI 10.1111/j.1399-6576.2005.06665.x.

Taddio A, Shah V, Stephens D, Parvez E, Hogan ME, Kikuta A, Koren G, Katz J. 2011. Effect of liposomal lidocaine and sucrose alone and in combination for venipuncture pain in newborns. Pediatrics 127(4):e940–947 DOI 10.1542/peds.2010-2914.
Tomlinson D, von Baeyer CL, Stinson JN, Sung L. 2010. A systematic review of faces scales for the self-report of pain intensity in children. *Pediatrics* 126(5):e1168–1198 DOI 10.1542/peds.2010-1609.

Tranel D, Damasio H. 1994. Neuroanatomical correlates of electrodermal skin conductance responses. *Psychophysiology* 31(5):427–438 DOI 10.1111/j.1469-8986.1994.tb01046.x.

Valkenburg AJ, Niehof SP, van Dijk M, Verhaar EJM, Tibboel D. 2012. Skin conductance peaks could result from changes in vital parameters unrelated to pain. *Pediatric Research* 71(4):375–379 DOI 10.1038/pr.2011.72.

von Baeyer CL, Marche TA, Rocha EM, Salmond K. 2004. Children’s memory for pain: overview and implications for practice. *Journal of Pain* 5(5):241–249 DOI 10.1016/j.jpain.2004.05.001.

Walco GA. 2008. Needle pain in children: contextual factors. *Pediatrics* 122(S3):125–9 DOI 10.1542/peds.2008-1055d.

Wallin BG. 1978. Recordings of impulses in unmyelinated nerve fibres in man: sympathetic activity. *Acta Anaesthesiologica Scandinavica Supplement* 70:130–136.

Wallin BG, Sundlof G, Delius W. 1975. The effect of carotid sinus nerve stimulation on muscle and skin nerve sympathetic activity in man. *Pflugers Archiv: European Journal of Physiology* 358(2):101–110 DOI 10.1007/BF00583921.

Wong DL, Baker CM. 1988. Pain in children: comparison of assessment scales. *Pediatric Nursing* 14(1):9–17.