Age Bias in Finger Vein Biometric Research

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Abstract: Finger vein biometrics have been implemented for authentication in a variety of contexts and places. Vein patterns are unique, easy to capture and resistant to surface wear and tear. However, there has been a lack of research on the effectiveness and stability of vein patterns in the elderly population (aged 60 years and above). A lack of inclusivity, has in the past ostracised senior citizens, from accessing basic amenities, such as pension payments and healthcare services. A lack of inclusion of the elderly in finger vein biometric research could result in the exclusion of elderly people from goods and services which use finger vein biometric authentication. As the global population ages, ensuring the usability of biometric technologies for the elderly is both a social and economic imperative.

1 INTRODUCTION

We live in a world where biometrics are commonly used as an authentication method. From fingerprint authentication in our mobile devices to national identification documents (Wagh et al., 2020), biometric authentication is ingrained in the daily lives of many people.

The finger vein biometric is a physiological biometric that has been gaining popularity (Yang et al., 2018). The intricate pattern of blood vessels presented underneath the epidermis of the skin, is what we refer to as the vein pattern. This is a highly distinctive pattern and can be used to uniquely identify individuals, including identical twins (Dev and Khanam, 2017).

Finger vein biometric capture is non-invasive, making it ideal in the current pandemic climate. Typically, the pattern is captured shining infra-red light through a finger (Yüksel et al., 2010). The haemoglobin in the blood absorbs the light, making the pattern appear darker and easier to capture (Yüksel et al., 2010). Veins lie under the skin, so cannot be easily destroyed or manipulated (Dev and Khanam, 2017). While these advantages make the finger vein biometric ideal for identification and authentication, there is limited research on how ageing impacts the need to re-enroll and how the current recognition and capture methods perform with the elderly population.

Age as a barrier in accessing biometric authentication is not a new concept. The roll-out of the Unique ID program in India saw the exclusion of the elderly population due to difficulty of enrolment. Due to lower elasticity of the skin in many older people, fingerprints were not able to be successfully captured. The Unique ID is now used as a primary form of identification across India, creating challenges for the elderly to access banking services and pension schemes (Rebera and Guihen, 2012). There is an upward trend in the percentage of the population above the age of 60 United Nations (2019), so elderly users need to be considered when designing many technologies.

Recent years have seen the adoption of finger vein recognition in commercial applications across the globe. By 2011, 70% of the financial institutions in Japan were using finger vein biometric authentication systems for identification and authentication of customers (Wang et al., 2011). The finger vein authentication device designed by Hitachi, is contactless and is used across most ATMs in Japan for authentication.

Finger vein authentication systems have also been successfully implemented in Poland (Hitachi, 2013). The Polish bank, Bank BPH (Bank Przemysłowo-Handlowy) has employed approximately 1800 finger vein authentication systems across their branches.

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The new technology replaces traditional means of authentication: identity documents, passwords and PINs (Hitachi, 2013). Now clients, need only declare their identity, and are authenticated by the device.

Turkey uses finger vein authentication, with devices implemented in hospitals and healthcare settings (Hitachi Global, 2014b). The Hitachi finger vein scanner has been implemented in the form of Wi-Fi scanners to allow for convenient mobile authentication of patients. In addition to this, the system is used as a means to manage payments and health insurance benefits (Hitachi Global, 2014b).

In the United Kingdom, the bank Barclays uses finger vein recognition systems for customer authentication. This technology was made available to their corporate banking clients in 2015, to tackle identity fraud that was impacting UK businesses (Hitachi Global, 2014a).

While advantageous, the widespread adoption of finger vein recognition systems may prove to be a burden for the elderly population. This paper explores the research gap: the elderly population has not been included in the implementation and study of finger vein biometric authentication.

2 MEDICAL CONDITIONS THAT IMPACT FINGER VEIN BIOMETRIC AUTHENTICATION

This section discusses the medical conditions that impact the performance of finger vein recognition systems. The feature extraction method of finger vein biometric systems are affected by vascular diseases that manifest as a change in the pattern of the finger vein. The elderly population are especially vulnerable to vascular disease (Rodgers et al., 2019), which may create an impact on the stability of a finger vein biometric in the elderly population.

Diseases of the veins, such as vein thrombosis, are caused by blood clots forming in the vein (CDC, 2020). This could affect the positioning and size of the vein pattern used in finger vein recognition systems. If a blood clot is formed in the finger after a person is enrolled, then they may fail at authentication, i.e., a false rejection. The elderly are particularly susceptible to vein thrombosis, with almost 60% of vein thrombosis incidents occurring in people above the age of 70. The individual risk of incurring thrombosis is up to 15% for 90 year olds (Engbers et al., 2010). When the events of vein thrombosis are compared between the elderly and the younger population, it becomes clear that aging is a prominent risk factor for vein biometric authentication failure.

Connective tissue diseases, such as mixed connective tissue disease (MCTD) or systemic sclerosis (SSc), lead to the abnormal growth of connective tissue (MedlinePlus, 2021). Diseases like SSc create arterial and venous abnormalities, along with microcirculation, impacting the blood flow, resulting in defective circulation in fingers (Allanore et al., 2007). Reduction in blood flow, conduces to a subsequent reduction in available haemoglobin to absorb light, impacting the performance of finger vein recognition systems and increasing the possibility of false rejection (Kono et al., 2015). A study that compared the recognition of finger vein authentication systems of research participants suffering from connective tissue disease against healthy research participants confirmed the higher rates of false rejection (Kono et al., 2015). SSc usually appears in adults within the 40-50 age group. Late onset SSc manifests itself in the elderly population above the age of 60 (Rimar, 2020). Thus, the elderly population are more vulnerable to connective tissue diseases, and could be adversely impacted due to the possibility of false rejection.

Injuries such as cuts and bruises can also negatively impact finger vein recognition rates, as they might be mistaken as veins (mofiria Corporation, 2020). This is a cause of concern for the elderly, as wounds tend to heal at slower rates when compared to the younger population (University of Pittsburgh, 2020).

Ageing brings with it an increased risk of vascular diseases, connective tissue disorders coupled by a slower rate of wound healing. Aging could have an adverse impact on successful recognition rates in finger vein authentication systems, resulting in false rejection of the elderly trying to authenticate themselves.

Finger vein biometric authentication has been proved to be useful, however the impact of the adoption on the elderly population is yet to be investigated. The world has seen a increase in the use of finger vein biometric for authentication in banking and healthcare. A system that potentially excludes a population demographic that comprises almost 20% of the adult population in 2020 (United Nations, 2019). Any difficulty in authentication could potentially lock the elderly out of accessing financial resources and critical care.

The failure of the Unique ID program in India to include the elderly population, emphasises the necessity of assessing the performance of finger vein recognition systems with elderly people.

3 PUBLIC FINGER VEIN DATABASES

There are several public finger vein databases that have been used for the study of finger vein recognition systems. For a comprehensive evaluation of the performance of any means of biometric authentication, the availability of datasets that reflect the user demographic is a requirement. Making datasets available to the research community supports researchers to ensure the ease of use and accuracy of the system. However, most of the available datasets do not capture the finger vein biometrics of elderly people. This section has conducted a investigation into the inclusion of the elderly in publicly available finger vein datasets.

3.1 Survey of Existing Literature on Finger Vein Recognition

This paper investigates the existing research on finger vein biometrics over the past decade. A major challenge that finger vein biometric research faces is the unavailability of a large dataset. The lack of testing in the elderly population has contributed a possible bias against the senior population. The existing literature does not provide sufficient evidence to guarantee the applicability of their findings beyond the age of 60. This is concerning, as recommendations are made about the suitability of their applications in real life scenarios, without taking into account the unavailability of data on performance in the elderly population (Liu and Song, 2012a). While there have been assumptions, that the experiments conducted on subjects below the age of 60 could model the behaviour of vein patterns in the older population (Damak et al., 2017), there is no concrete evidence that suggests age based extrapolation is valid.

3.2 Methodology

We searched for publicly available databases and research studies of finger vein biometrics. We limited our research to papers that have been published in English within the last decade. Anything published before the year 2011 has not been considered in this survey.

The publications and databases included in this paper have been found by using the following keywords in Google Scholar : "finger vein authentication", "age bias in finger vein biometric research", "age bias in biometrics", "finger vein recognition".

Many of the databases do not have detailed information on the demographics of their research participants. In these cases, world population statistics (United Nations, 2019) are used to estimate the number of people above the age of 60.

- For the databases published between the years of 2011 and 2014, we use the population statistics of 2010, where people aged above 60 are 16% of the adult population. Where no age detail is given, we estimate that 16% of the research participants are 60 and above.
- For databases published between the years of 2015 and 2019, we use the population statistics of 2015, where people who are 60 and above comprise 17% of the adult population. Where no age detail is given, we estimate that 17% of the research participants are 60 and above.

3.3 Evaluation of Finger Vein Databases

Table 1 collates publicly available finger vein databases and the different studies that have analysed them. The total number of research participants for each dataset is compared with the number of research participants above the age of 60. Most datasets have completely excluded the elderly population as shown in the table.

Most datasets do not describe in detail the age distribution of the research participants. In those cases an estimate was made, see section 3.2. Estimated numbers are labeled with an asterisk (*). It is important to note that amongst the databases considered in this paper (see Table 1) , the databases MMCBNU_6000, PLUSVeinFV3 and PROTECT are the only databases that state the inclusion of research participants above the age of 60.

Overall, an estimated 6% of the total test population are adults above the age of 60. Thus, compared with 19% of the global adult population (United Nations, 2019) the available data is insufficient to substantiate that the elderly population are accounted for. Extrapolating results from such a biased sample is likely to draw biased conclusions.

4 CONCLUSIONS

In conclusion, very few people above the age of 60 have participated in finger vein research studies. The longevity and stability of vein patterns cannot be assumed. Medical conditions like vein thrombosis and connective tissue diseases can impact the performance of finger vein recognition systems, which can lead to false rejection. The roll-out of finger vein systems for recognition and authentication could exclude

Table 1: Public Finger Vein Databases, tabulated the number of research participants aged over 60 years. * indicates estimated numbers.

S No	Database name	Total number of research participants	No of research participants 60+	Published works that used the database	Comments
1	MMCBNU_6000	100	3	(Lu et al., 2013), (Yang et al., 2014a),(Shaheed et al., 2018)	
2	SDUMLAHMT	106	0	(Yin et al., 2011), (Shaheed et al., 2018), (Yang et al., 2014a), (Lu et al., 2018)	
3	THUFVFDT	220	0*	(Wenming et al., 2014), (Yang et al., 2014b), (Yang et al., 2014a), (Shaheed et al., 2018)	The study was conducted in China, where the retirement age for is 60. The participants in the study were the staff and students of the university, thus, none of the participants are above the age of 60.
4	HKPUFV	156	2*	(Kumar and Zhou, 2011), (Yang et al., 2014a), (Shaheed et al., 2018), (Lu et al., 2018)	93% of the participants were younger than 30 years. In 2010, adults in the 60+ age bracket account for 16.2% of the adult world population. (United Nations, 2019).
5	UTFV	60	2*	(Ton and Veldhuis, 2013), (Yang et al., 2014a), (Vanoni et al., 2014)	82% of the participants are in the age range of 19–30. In 2010, adults in the 60+ age bracket account for 16.2% of the world adult population (United Nations, 2019).
6	VERA	110	20*	(Tome et al., 2015),(Vanoni et al., 2014),(Shaheed et al., 2018),(Tome et al., 2014)	The participants are aged between 18 and 60. The database was published in 2015. In 2015, adults in the 60+ age bracket account for 17.71% of the adult world population (United Nations, 2019).
7	FVUSM	123	0	(Mohd Asaari et al., 2014), (Shaheed et al., 2018)	
8	PLUSVein-FV3	60	11*	(Kauba et al., 2018)	The participants are aged betwean 18-79 year. In 2015, adults in the 60+ age bracket account for 17.71% of the adult world population (United Nations, 2019).
9	PROTECT multimodal DB	47	9*	(University of Reading, 2017)	The participants are aged between 21-76 years. In 2015, adults in the 60+ age bracket account for 17.71% of the adult world population (United Nations, 2019).
10	KTDeaduk-FV	30	5*	(Lee et al., 2011)	In 2010, adults in the 60+ age bracket account for 16.2% of the adult world population(United Nations, 2019).
11	CFVD	13	0	(Zhang et al., 2013)	
12	S-EMB-Laser-FV	100	0	(Liu and Song, 2012b)	
13	Gjøvik University College, Norway -1	41	1*	(Raghavendra et al., 2014)	90% of participants are between the ages of 20-35. In 2010, adults in the 60+ age bracket account for 16.2% of the adult world population (United Nations, 2019).
14	Wuhan University, China	106	18*	(Yang et al., 2012)	The participants are between the ages of 19-60. In 2010, adults in the 60+ age bracket account for 16.2% of the total world population (United Nations, 2019).
15	Shandong. Univ	34	0	(Xi et al., 2013)	
16	USM	51	0	(Rosdi et al., 2011)	
17	Civil Aviation University of China	100	17*	(Yang and Shi, 2014)	In 2010, adults in the 60+ age bracket account for 16.2% of the adult world population (United Nations, 2019).
18	Gjøvik University-2	125	0	(Raghavendra and Busch, 2015)	
	Total	1582	88*		

a large part of the dependant population from accessing basic amenities, including banking and health services.

4.1 Recommendations for Future Research

There is an upwards trend in the proportion of the world's population that are over the age of 60 (United Nations, 2019). Thus, there is merit in observing the way finger vein biometric authentication behaves when implemented amongst the elderly. This includes the ease of enrollment and the success rate of authentication, including False Accept Rate (FAR) and False Reject Rate (FRR). Therefore, research on finger vein biometric systems needs to include elderly participants to ensure that ground-breaking technology does not exclude a significant portion of the population.

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REFERENCES

Allanore, Y., Seror, R., Chevrot, A., Kahan, A., and Drapé, J. L. (2007). Hand vascular involvement assessed by magnetic resonance angiography in systemic sclerosis. *Arthritis and rheumatism*, 56(8):2747–2754.

CDC (2020). What is venous thromboembolism? https://www.cdc.gov/ncbddd/dvt/facts.html.

Damak, W., Boukhris Trabelsi, R., Damak Masmoudi, A., Sellami, D., and Nait-Ali, A. (2017). Age and gender classification from finger vein patterns. In Madureira, A. M., Abraham, A., Gamboa, D., and Novais, P., editors, *Intelligent Systems Design and Applications*, pages 811–820, Cham. Springer International Publishing.

Dev, R. and Khanam, R. (2017). Review on finger vein feature extraction methods. In *2017 International Conference on Computing, Communication and Automation (ICCCA)*, pages 1209–1213.

Engbers, M. J., van Hylckama Vlieg, A., and Rosendaal, F. R. (2010). Venous thrombosis in the elderly: incidence, risk factors and risk groups: Risk factors for venous thrombosis in the elderly population. *Journal of thrombosis and haemostasis*, 8(10):2105–2112.

Hitachi (2013). Finger vein technology for bank bph (poland). https://www.hitachi.eu/en/case-studies/finger-vein-technology-bank-bph-poland.

Hitachi Global (2014a). Barclays first in uk to launch new biometric reader for customers. https://www.hitachi.com/New/cnews/month/2014/09/140905.html.

Hitachi Global (2014b). Hitachi and mig introduce mobile wi-fi biometric scanners in turkish hospitals. https://www.hitachi.com/New/cnews/month/2014/07/140709a.html.

Kauba, C., Prommegger, B., and Uhl, A. (2018). Focussing the beam - a new laser illumination based data set providing insights to finger-vein recognition. In *2018 IEEE 9th International Conference on Biometrics Theory, Applications and Systems (BTAS)*, pages 1–9.

Kono, M., Miura, N., Fujii, T., Ohmura, K., Yoshifuji, H., Yukawa, N., Imura, Y., Nakashima, R., Ikeda, T., Umemura, S., Miyatake, T., and Mimori, T. (2015). Personal authentication analysis using finger-vein patterns in patients with connective tissue diseases - possible association with vascular disease and seasonal change. *PloS one*, 10(12):e0144952–e0144952.

Kumar, A. and Zhou, Y. (2011). Human identification using finger images. *IEEE transactions on image processing : a publication of the IEEE Signal Processing Society*, 21:2228–44.

Lee, E. C., Jung, H., and Kim, D. (2011). New finger biometric method using near infrared imaging. *Sensors*, 11(3):2319–2333.

Liu, Z. and Song, S. (2012a). An embedded real-time finger-vein recognition system for mobile devices. *IEEE transactions on consumer electronics*, 58(2):522–527.

Liu, Z. and Song, S. (2012b). An embedded real-time finger-vein recognition system for mobile devices. *IEEE Transactions on Consumer Electronics*, 58(2):522–527. Copyright - Copyright The Institute of Electrical and Electronics Engineers, Inc. (IEEE) May 2012; Last updated - 2012-07-07.

Lu, Y., Xie, S. J., Yoon, S., Wang, Z., and Park, D. S. (2013). An available database for the research of finger vein recognition. In *2013 6th International Congress on Image and Signal Processing (CISP)*, volume 01, pages 410–415.

Lu, Y., Yang, G., Yin, Y., and Xi, X. (2018). Finger vein recognition with anatomy structure analysis. *IEEE Transactions on Circuits and Systems for Video Technology*, 28(8):1892–1905. Copyright - Copyright The Institute of Electrical and Electronics Engineers, Inc. (IEEE) 2018; Last updated - 2019-02-01.

MedlinePlus (2021). Scleroderma. https://medlineplus.gov/scleroderma.html.

mofiria Corporation (2020). Frequently asked questions. https://www.mofiria.com/en/faq.

Mohd Asaari, M. S., Suandi, S. A., and Rosdi, B. A. (2014). Fusion of band limited phase only correlation and width centroid contour distance for finger based biometrics. *Expert systems with applications*, 41(7):3367–3382.

Raghavendra, R. and Busch, C. (2015). Exploring dorsal finger vein pattern for robust person recognition. In *2015 International Conference on Biometrics (ICB)*, pages 341–348.

Raghavendra, R., Raja, K. B., Surbiryala, J., and Busch, C. (2014). A low-cost multimodal biometric sensor to capture finger vein and fingerprint. In *IEEE International Joint Conference on Biometrics*, pages 1–7.

Rebera, A. P. and Guihen, B. (2012). Biometrics for an ageing society societal and ethical factors in biometrics and ageing. In *2012 BIOSIG - Proceedings of the International Conference of Biometrics Special Interest Group (BIOSIG)*, pages 1–4.

Rimar, D. (2020). *Systemic Sclerosis in the Elderly*, pages 207–228. Springer International Publishing, Cham.

Rodgers, J. L., Jones, J., Bolleddu, S. I., Vanthenapalli, S., Rodgers, L. E., Shah, K., Karia, K., and Panguluri, S. K. (2019). Cardiovascular risks associated with gender and aging. *Journal of cardiovascular development and disease*, 6(2):19.

Rosdi, B. A., Shing, C. W., and Suandi, S. A. (2011). Finger vein recognition using local line binary pattern. *Sensors*, 11(12):11357–11371.

Shaheed, K., Liu, H., Yang, G., Qureshi, I., Gou, J., and Yin, Y. (2018). A systematic review of finger vein recognition techniques. *Information*, 9(9).

Tome, P., Raghavendra, R., Busch, C., Tirunagari, S., Poh, N., Shekar, B. H., Gragnaniello, D., Sansone, C., Verdoliva, L., and Marcel, S. (2015). The 1st competition on counter measures to finger vein spoofing attacks. In *2015 International Conference on Biometrics (ICB)*, pages 513–518.

Tome, P., Vanoni, M., and Marcel, S. (2014). On the vulnerability of finger vein recognition to spoofing. In *2014 International Conference of the Biometrics Special Interest Group (BIOSIG)*, pages 1–10.

Ton, B. T. and Veldhuis, R. N. J. (2013). A high quality finger vascular pattern dataset collected using a custom designed capturing device. In *2013 International Conference on Biometrics (ICB)*, pages 1–5.

United Nations (2019). World population prospects 2019. https://population.un.org/wpp/Download/Standard/Population/.

University of Pittsburgh (2020). Why do older people heal more slowly? https://www.pitt.edu/pittwire/features-articles/why-do-older-people-heal-more-slowly.

University of Reading (2017). Protect multimodal dataset. http://projectprotect.eu/dataset/.

Vanoni, M., Tome, P., El Shafey, L., and Marcel, S. (2014). Cross-database evaluation using an open finger vein sensor. In *2014 IEEE Workshop on Biometric Measurements and Systems for Security and Medical Applications (BIOMS) Proceedings*, pages 30–35.

Wagh, D. P., Fadewar, H. S., and Shinde, G. N. (2020). Biometric finger vein recognition methods for authentication. In Iyer, B., Deshpande, P. S., Sharma, S. C., and Shiurkar, U., editors, *Computing in Engineering and Technology*, pages 45–53, Singapore. Springer Singapore.

Wang, K., Ma, H., Popoola, O., and Liu, J. (2011). *Finger vein recognition*.

Wenming, Y., Huang, X., Zhou, F., and Liao, Q. (2014). Fusion of finger vein and finger dorsal texture for personal identification based on comparative competitive coding. *Information Sciences*, 268:20–32.

Xi, X., Yang, G., Yin, Y., and Meng, X. (2013). Finger vein recognition with personalized feature selection. *Sensors*, 13(9):11243–11259.

Yang, G., Xi, X., and Yin, Y. (2012). Finger vein recognition based on a personalized best bit map. *Sensors*, 12(2):1738–1757.

Yang, J. and Shi, Y. (2014). Towards finger-vein image restoration and enhancement for finger-vein recognition. *Information sciences*, 268:33–52.

Yang, L., Yang, G., Yin, Y., and Xi, X. (2018). Finger vein recognition with anatomy structure analysis. *IEEE Transactions on Circuits and Systems for Video Technology*, 28(8):1892–1905.

Yang, L., Yang, G., Yin, Y., and Zhou, L. (2014a). A survey of finger vein recognition. In Sun, Z., Shan, S., Sang, H., Zhou, J., Wang, Y., and Yuan, W., editors, *Biometric Recognition*, pages 234–243, Cham. Springer International Publishing.

Yang, W., Huang, X., Zhou, F., and Liao, Q. (2014b). Comparative competitive coding for personal identification by using finger vein and finger dorsal texture fusion. *Information sciences*, 268:20–32.

Yin, Y., Liu, L., and Sun, X. (2011). Sdumla-hmt: A multimodal biometric database. In Sun, Z., Lai, J., Chen, X., and Tan, T., editors, *Biometric Recognition*, pages 260–268, Berlin, Heidelberg. Springer Berlin Heidelberg.

Yüksel, A., Akarun, L., and Sankur, B. (2010). Biometric identification through hand vein patterns. In *2010 International Workshop on Emerging Techniques and Challenges for Hand-Based Biometrics*, pages 1–6.

Zhang, C., Li, X., Liu, Z., Zhao, Q., Xu, H., and Su, F. (2013). The cfvd reflection-type finger-vein image database with evaluation baseline. In Sun, Z., Shan, S., Yang, G., Zhou, J., Wang, Y., and Yin, Y., editors, *Biometric Recognition*, pages 282–287, Cham. Springer International Publishing.