Original Article

Evaluation of Images Marked as Child Abuse by Digital Systems in Terms of Forensic Age Determination: A Retrospective Study

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Abstract

Background: The utilization of children in digital recordings with explicit content is subject to significant penalties on a global scale. In the context of legal proceedings, it is of significant legal and social importance to correctly determine whether the images examined belong to a child or an adult. **Aim:** It is aimed to reveal the problems encountered in the expert witnessing process, to reveal the methods that can be used in age determination, and to contribute to the improvement of the expert witnessing process with the data examined in age determination from digital images. **Methods:** The decisions of forensic medicine experts on the digital images dated between 01/01/2015 and 31/12/2022, in which opinions were expressed as to whether the images included children and, if so, the age range of the children, were evaluated retrospectively. **Results:** Over the specified period, 349 digital materials were examined from 69 perpetrators as part of 67 different court cases. It was observed that 67.9% (n = 237) of the potential victims were female and 81.2% (n = 56) of the suspect were male. In cases where only limited image data were available, the age range could be determined in only 20% of cases. In contrast, when the majority of body parts were visible, the age range was determined in 70.8% of cases. **Conclusion:** In light of the discrepancies between our findings and those of intelligent systems, it is evident that novel methodologies and studies are required, particularly for adolescent populations. It is an inevitable consequence of erroneous opinion that problems will be created for both the victim and the suspect.

Keywords: *Child sexual abuse, digital images, forensic age estimation, Internet*

Introduction

One of the most pivotal aspects of the identification process is the determination of the individual's age.[1] Age determination procedures are employed in numerous medical and social sciences, including anthropology, radiology, pediatrics, and orthopedics. Additionally, it is a pivotal subject within the domains of forensic medicine and forensic sciences. The question of age determination is of great consequence in both criminal and civil court proceedings. Forensic medicine employs age determination procedures in a multitude of contexts, including at the request of the individual and at the request of the courts.[2] In developed countries, age determination is typically conducted for the purpose of identification. However, the assessment of bone age-chronological age concordance in forensic contexts and the evolving sociocultural landscape, particularly in light of recent migration patterns, has led to an increased emphasis on the challenges associated with identity documentation and the lack of birth registration among immigrants.[3,4]

In forensic medical evaluations, it is essential to ascertain the true age of the individual in order to form an opinion about the criminal and legal responsibility of the victim or suspect.[1,2,5,6] Moreover, as technology progresses,

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new forms of criminal activity that necessitate age determination emerge. One such emerging area is the possession and/or dissemination of explicit images of children in the virtual/digital environment, which has emerged alongside the spread of the Internet and digital technologies.[5,6]

Pornography is defined as any written, visual, or auditory content that is created with the intention of eliciting sexual desire, excitement, or arousal yet does not possess any discernible esthetic value. In contrast, child sexual abuse refers to the sexual exploitation of minors in such content.[7,8] The utilization of children in digital recordings with explicit content is subject to significant penalties on a global scale.[7,8] The United Nations-issued Convention on the Rights of the Child, which was implemented by member nations on different dates, addresses the issue of child exploitation, including sales of children, child prostitution, and child sexual abuse.[9]

The United Nations Children's Fund (UNICEF) is implementing a series of projects in collaboration with various institutions with the objective of ending violence against children by the year 2030.[10] A dozen legal and academic studies have been proposed for all partners of the subject. Additionally, studies pertaining to social awareness have also attracted attention.[11] Furthermore, it is important to acknowledge the contributions of various institutions and organizations outside the European Union in raising public awareness and shaping the legal framework of the process.[12,13] While these regulations were enacted by governmental entities, specific obligations were imposed on social media companies. These companies were granted the authority to disseminate information pertaining to cybercrimes to state authorities. However, their primary responsibility is to prevent the initial publication and dissemination of such data.[14]

In accordance with the aforementioned legal regulations and treaty texts, the production, possession, and distribution of sexual content, including children, is a criminal offense and necessitates criminal prosecution. The most significant challenge in such cases is determining whether the pornographic material in question contains images of children. This involves evaluating the age of the individuals depicted in the images, which could potentially lead to a forensic investigation.[15] Images of child sexual abuse are akin to a digital crime scene, necessitating a meticulous and comprehensive analytical approach.[16]

The most commonly utilized method for age determination in clinical practice is the examination of the ossification centers of the long bones and the ossification level of the connective cartilage between the epiphysis and diaphysis.[2,17–19] In addition to medical parameters such as height, weight, bone and tooth examinations, signs of puberty, secondary sex characteristics, hair, eye, and skin findings, forensic knowledge indicates that issues such as population statistic records, military service, education periods, and mental development can be evaluated when determining age.

Nevertheless, the field of age determination through images is constrained by significant limitations. While the presence of certain physical characteristics, such as skin color, wrinkles, and sexual character development in specific body parts (e.g. pubic and armpit hair, breast development), can be discerned in images, it is important to recognize that external appearances may not align with an individual's actual age due to environmental and genetic factors. For instance, an individual who appears to be a child may possess characteristics more commonly associated with an adult, and vice versa.[5] The osteological, dental, ocular, and software-based age determination methods proposed and utilized in the literature are not applicable for precise age determination from the images as the face-to-face examination of the victim is not feasible in such cases.

Furthermore, in digital images, numerous programs/applications that estimate age from the face area have been developed. Intelligent systems can estimate age with markers such as general body and facial appearance, skin color, and wrinkles on the face. However, limited image quality, the use of make-up and esthetic applications, and body and/or face filter programs are among the factors that make the process difficult.[20]

Subject and Methods

In this study, the expert reports prepared by the Karabük Forensic Medicine Branch Directorate between January 1, 2015 and December 31, 2022, regarding digital media images in which an expert opinion was provided regarding the identity and age of the subjects, were subjected to analysis. The images analyzed in the reports include cases of sexual offenses committed by Internet users residing in the study area in Turkey according to their IP addresses. In the preliminary evaluation conducted by the intelligent systems utilized by national and international judicial authorities, the cases were deemed to involve children. Consequently, we were requested to provide an expert opinion for the final evaluation. According to the results of the report, cases were categorized into four main sections in terms of age

groups as '*unknown, >18 years, possibly <18 years, very high probability <18 years'*. In addition, since the issue of whether the images belong to children is important in the legal evaluation in our country, no subgrouping was made in the child age group. In the pertinent reports, the sociodemographic characteristics (age, gender, etc.) of the suspect from whom the images were obtained, the type of image (photograph or video), the presence of restrictions/limitations in the image (resolution, shooting angle, etc.), the content of the image, the purpose for which the image was uploaded, the body parts contained in the image, the decisions, and the parameters used in age determination were subjected to analysis.

When determining whether the image is limited/restricted or not, deficiencies such as insufficient coverage of body regions that can be used for age determination, inclusion of a part of the image from an inappropriate distant angle, and/or low resolution were taken into account. The submitted digital materials were made clearer to the extent that pixel enhancement was possible, but photographs that could not be pixel-enhanced or that were not clear and images that did not have a resolution of at least 480 × 600 pixels in the image frame where the victim's body covered the maximum area in the frame were classified as low quality and included in the 'limited' image group.

In accordance with the law on the protection of personal data in our country, it is forbidden to store some private data of individuals by individuals or institutions. The expert does not have the right to archive the image records of the cases where an opinion is given on digital images. In addition, the identity information of the victim and/or suspect is not recorded during the study process.

In order to ascertain whether the image in question was sexually motivated, the characteristics identified by the American Psychological Association (APA) were taken into consideration.[5,21]

The data set was subjected to descriptive statistical analysis, with the objective of elucidating the relationships between the variables of image content, image type, information about the perpetrator, and decision results. The frequency of determining the age group according to the material type and image quality was determined by Pearson's Chi-square test, while the frequency of determining the age group according to whether the body parts visible in the image are limited or the whole body was analyzed with Fisher's exact test since some data were less than expected counts. Whether the parameters used differed according to whether the age of the patient was determined or not was evaluated with the Chi-square test for each parameter (facial features, skin features, armpit hair, trunk hair, breast development, pubic hair, external genitalia, extremity hair, body stature, penile/scrotal appearance), and Phi (ϕ) value of effect size and confidence interval calculations were made. The level of significance for all tests was set at $P = 0.05$. All statistical analyses were conducted using IBM SPSS 22.0 (MA, USA).

The study was approved by the Non-Interventional Clinical Research Ethics Committee of Karabük University on February 27, 2023, and was assigned the number 2023/1269.

Results

A total of 349 distinct materials were examined between the specified dates. Of these, 269 were photographs (representing 77.1% of the total) and 80 were videos (22.9%). These materials were seized from 69 different perpetrators within the scope of 67

Table 1: Features of the evaluated materials

		Number	Percentage
Victim sex	Male	*n*=111	31.8%
	Female	*n*=237	67.9%
	Unknown	*n*=1	0.3%
	Total	*n*=349	100.0%
Material type	Photograph	*n*=269	77.1%
	Video	*n*=80	22.9%
Purpose*	Sexual	*n*=241	69.1%
	Nonsexual	*n*=11	3.2%
	Undetermined	*n*=97	27.8%
Content shooting location	Inside	*n*=277	79.4%
	Outside	*n*=72	20.6%
Accompanying objects	None	*n*=246	70.5%
	Adult male	*n*=43	12.3%
	Adult female	*n*=21	6.0%
	Pediatric male	*n*=15	4.3%
	Animal	*n*=10	2.9%
	Object	*n*=3	0.9%
	Unidentified person	*n*=11	3.2%
Source	Facebook	*n*=49	14.0%
	Instagram	*n*=14	4.0%
	Twitter	*n*=260	74.5%
	WhatsApp	*n*=24	6.9%
	meetme.com	*n*=2	0.6%
	Total	*n*=349	100.0%
Age groups of victims	Very high probability <18 years	*n*=82	23.5%
	Possibly <18 years	*n*=30	8.6%
	>18 years	*n*=125	35.8%
	Unknown	*n*=112	32.1%
	Total	*n*=349	100.0%

While determining whether the image was sexually orientated or not, the characteristics determined by APA (American Psychological Association) were taken into consideration.[5,21]

different court files. Upon examination of the genders of the potential victims depicted in the reported digital materials, it was determined that 67.9% (n = 237) were female. In one instance, the gender could not be ascertained due to limitations imposed by the image itself. The characteristics of the examined materials are presented in Table 1.

The analysis revealed that the type of material (photograph or video) did not have a statistically significant impact on the age group determination (P = 0.892).

When the contents of the reported images were analyzed, it was observed that 94.3% (n = 329) were in the unlimited group. It was also found that the facial region could be seen in 67% (n = 234) and the genital region in 80.8% (282) of the images. Identifiable body parts are shown in Figure 1.

In only 20% (n = 4) of cases with limited image data, the age range could be determined. In this group, which is defined as low quality and low content, age determination is possible on the basis of the body measurements evident in the image and, if present, the facial appearance of the person in the image content, which would indicate that the subject is a small child or an adult. However, in 70.8% (n = 233) of cases involving whole-body materials, the age range was successfully identified. A statistically significant difference (P = 0.01) was observed in the age range determination between the materials with limited image data and those with all body unlimited features.

In 69.0% (n = 232) of cases with high image quality, the age group was determined. In contrast, only 38.5% of low-quality images allowed for the identification of decidable materials. A statistically significant difference

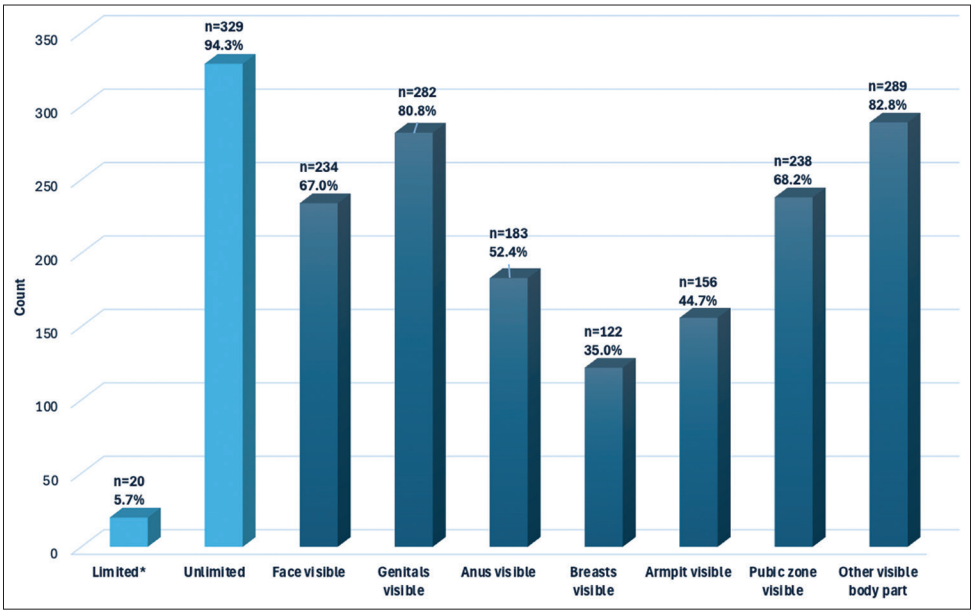

Figure 1: Visible parts on images
*When determining whether the image is limited or not, deficiencies such as insufficient coverage of body regions that can be used for age determination, inclusion of a part of the image from an inappropriate distant angle, and/or low resolution were taken into account

Table 2: Parameters used to determine age groups

Investigated parameters	Determined	Unknown	Total	*P*	φ	95% Confidence Intervals	
						Lower	Upper
Facial features	152	81	233	0.130	0.08	0.42	1.12
Skin features	57	17	74	0.058	0.10	0.98	3.21
Armpit hair	52	8	60	0.001	0.18	1.67	7.99
Trunk hair	51	21	72	0.551	0.03	0.67	2.09
Breast development	116	66	182	0.081	0.09	0.42	1.05
Pubic hair	184	68	252	0.001	0.18	1.38	3.66
External genitalia	131	75	206	0.038	0.11	0.38	0.98
Extremity hair	42	0	42	<0.001	0.25	1.45	1.71
Body stature	192	90	282	0.885	0.01	0.59	1.84
Penile/scrotal appearance	72	1	73	<0.001	0.34	6.63	353.68

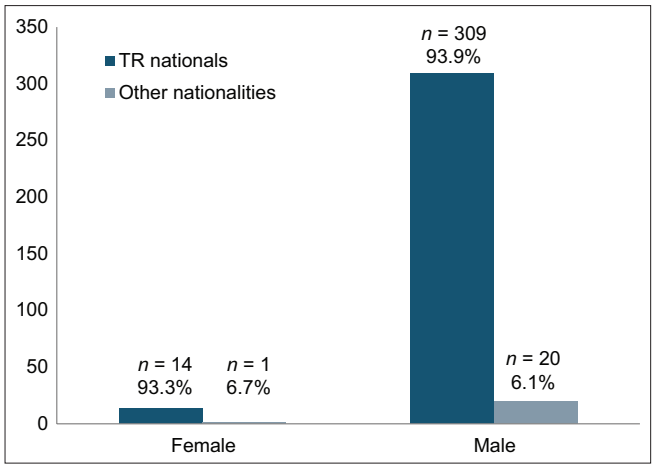

Figure 2: Features of suspects

was observed between the two groups in terms of decision-making ($P = 0.02$).

The findings revealed that the age group in question exhibited a statistically significant level of determination in the materials where armpit hair, pubic hair, external genitalia, extremity hair, and penile/scrotal appearance were evaluated in terms of the examinations conducted to determine the age groups and the subsequent decision-making based on the characteristics observed in these examinations [Table 2].

The mean age of the suspects was 30.33 years (SD = 10.15), and 81.2% (n = 56) were male. Approximately 94% of the suspects were in Turkish nationality [Figure 2].

Discussion

Child sexual abuse represents a significant digital threat to all societies, irrespective of geographical location. The advent of the Internet and the subsequent proliferation of child pornography have fundamentally altered the dynamics of child abuse. The increased use of social media and the proliferation of social media applications have given rise to significant challenges in terms of auditability. One of the most crucial initiatives undertaken to address this threat is the detection of pornographic images of minors being victimized online, facilitated by the increasing efficacy of global digital information control centers. However, it is challenging to ascertain whether the identified images depict children and/or contain criminal elements.

Despite considerable research, computer-aided studies on deep learning have yet to achieve significant success in estimating age within the adolescent age group.[22] It is well documented that there is considerable variability in the rate of maturation, particularly in sexual maturation, between individuals. This is due to a number of factors, including biological, pathological, and environmental influences. Moreover, a substantial body of literature has examined the discrepancy in the pace of sexual maturation across diverse populations.[23,24] A further significant drawback of such assessments is the inability to conduct a comprehensive medical examination, which encompasses inspection and palpation.

The images included in the reports examined in this study were cases that were either sent or downloaded by users from social media and digital applications. The aforementioned cases were initially identified by the intelligent systems of the judicial authorities as involving children. All suspects were residents of Turkey, and the content included images of both Turkish and foreign individuals. In the reports examined, it was observed that 77.1% of the cases were photographs and 22.9% were videos. Upon examination of the genders of the potential victims depicted in the digital materials, it was determined that 67.9% (n = 237) were female, which aligns with the findings of previous literature on the subject.[25] However, it was observed that the gender ratios obtained from the images exhibited a greater prevalence of males compared to the findings reported in the existing literature on child abuse victims.[26] In light of the research on the dissemination of images of the male genitalia among men, this distinction is regarded as tantamount to child sexual abuse. However, it is postulated that the motivation behind such actions may be rooted in the perception of the genital areas of male children as a subject of humor.[27,28]

In the case of high-quality images, the age group was determined in 69% of instances. In contrast, in images of lower quality, the rate of decision-making was 38.5%. In addition, while this rate was 20% in limited images, it was 70.8% in unlimited whole-body images. A statistically significant difference was identified within the two groups separately in terms of decision-making. The estimation of an individual's age through a photograph or video with restricted shooting angles, image quality, and incomplete body coverage is a common challenge encountered during image evaluation. Furthermore, evaluations based on black-and-white or compressed files with poor image quality are also subject to certain limitations. This point, together with the deadlocks in certain age groups in image age determination, are two of the most important issues that make the solution of the problem difficult for the expert and intelligent systems.

The Internet Watch Foundation's 2021 annual report indicates that the number of reports containing videos and photos of child abuse increased by 374% during the pandemic, with the 11–13 age group exhibiting the

highest prevalence.[29] Our research indicates that 74.5% of the photographs analyzed were obtained from Twitter, 14% from Facebook, 6.9% from WhatsApp, and 4% from Instagram. The findings of this study will also assist in determining the necessary measures to be taken at the local level as they demonstrate the extent to which suspects utilize social media platforms to disseminate images of children in our region.

A review of the characteristics of the suspects revealed that the mean age was 30.33 years (SD = 10.15) and 81.2% (n = 56) were male. This finding corroborates the male suspect profile between the ages of 26 and 40, which has been widely documented in the literature.[29,30]

It has been proposed that the term "sexual maturity rating" may be a more appropriate designation than the Tanner classification in the context of the analysis of images containing child sexual abuse. This is due to the recognition that the processes of onset, development, and completion of puberty have undergone changes over time.[16] The statistical significance of the age group was determined in the materials evaluated, including armpit hair, pubic hair, external genitalia, extremity hair, and penile/scrotal appearance. This determination was made based on the examinations conducted to ascertain the age groups and the subsequent decision-making processes involving the characteristics identified through these examinations. In images of child sexual abuse crimes, the face or whole body of the perpetrator or victim may be partially or fully visible, depending on the camera used, ambient light, and shooting angle. It is not always visible, and in some cases, it is not depicted at all. Given the prevalence of such scenarios, it is not always feasible to employ existing software technologies in the investigation of child sexual abuse crimes. In the presence of all body areas that allow evaluation, developed programs or indices can be used.

While examinations of tooth development can be useful for age determination, images are typically insufficient for such an analysis. Another method, which has yet to be subjected to rigorous analysis, is based on the evaluation of facial features and is therefore more subjective and controversial.[22] In a study conducted by Cattaneo *et al*.,[31] 353 female and 20 male cases aged 6, 10, 14, and 18, consisting of citizens of Germany, Italy, and Lithuania, were evaluated from face photographs. The researchers employed a series of indexes to classify the subjects, with an accuracy rate of 69–80% in determining the age. The study concluded that developing indices on a national level, rather than focusing on secondary sex characteristics, would yield more precise age estimation results. A more objective and reliable evaluation may be possible through the use of facial measurements. As it is challenging to ascertain an individual's age with certainty, it is proposed that a more precise method would be to determine age through the use of specialized software.[20,32]

In particular, the application of advanced cosmetology techniques, including hair removal and sophisticated makeup, can contribute to the perception of a younger or older appearance than what might be expected. A further issue arises from the inability to ascertain information regarding the race, genetic characteristics, and potential health issues of the individual depicted in the image when estimating the age from digital image recordings. For these reasons, the expert conducting the examination should take into account all these issues and base his opinion on the report submitted, which should be based on concrete data. In such cases, the most valuable method for determining age is the age determination method based on growth and developmental characteristics. In the method based on growth-development characteristics, the physical properties that can be evaluated include height, weight, examinations, signs of puberty, secondary sex characteristics, hair, facial appearance, and skin findings. The objective is to prevent potential errors that could result from evaluating these parameters collectively.

The crucial aspect of estimating the age of children through image analysis is to ascertain whether the image in question pertains to the prepubertal or postpubertal period. It can be challenging to ascertain the preadult phase; however, it is typically feasible to determine whether the individual is in the prepubertal or postpubertal stage. Nevertheless, the age of sexual adulthood has been legally established at 18 in various countries worldwide, as exemplified by the legislation in Turkey. It thus appears that the issue frequently concerns the challenging task of establishing whether individuals who have reached sexual maturity have reached the age threshold of 13–18, which differs by country.[33]

The upper age limit for the onset of hair and body muscle development on the face, pubis, armpits, and other body parts is approximately 12 years of age.[34] However, in the reports prepared by us, it was taken into consideration that there may be significant deviations in these findings depending on different variables in individuals. In the decisions evaluated in our study, age was determined through a comprehensive visual inspection and evaluation of all relevant areas. This included a general body analysis, if visible, anatomical reference points in the facial area, dental assessment, genital area, breast, and, in the images, the armpit. It was decided that 35.8% of the cases were older than 18 years of age, 23.5% were younger than 18 years of

age with a high probability, 8.6% were possibly younger than 18 years of age, and 32.1% of the cases could not be determined. Briefly, our assessment of cases identified as children by intelligent systems revealed that only one-third of these cases were correctly identified. Furthermore, it is postulated that, in addition to the aforementioned false positive cases, there may also be instances where the evaluation is classified as false negative. This demonstrates the proclivity of these systems to misjudge children, highlighting an area that requires further improvement. Such misjudgements have the potential to result in significant ramifications in domains where these systems are deployed, including health, education, and social services. In some instances, this can lead to severe legal consequences. Consequently, it is imperative that more research be conducted to enhance the training of intelligent systems and guarantee their ability to accurately identify children.

A study has shown that there has been a significant increase in the use of infants and babies in the pornography industry.[16] In the case files that were examined, seven (representing 2% of the images and 10.4% of the criminal files) of them contained images of newborn male infants. Despite the absence of any discernible sexual content, it remains uncertain whether these images were utilized for the purpose of sexual gratification.

In a study conducted in Italy and Germany, a group of specialist physicians from different branches were asked to determine whether there were children in the photographs of 11 female actresses known to be over the age of 18 who were employed in the porn industry. Additionally, the physicians were asked to specify which body part (face, breast, pubic hair growth, other) was evaluated in making a decision. Three groups were constituted, comprising experts in the fields of obstetrics, pediatrics, and forensic medicine. A control group was also formed, comprising individuals from nonmedical professions. Similarly, the two studies yielded no successful results. The studies revealed that forensic medicine specialists demonstrated the greatest success in determining age, with accuracy rates of 60% in Italy and 50% in Germany. In contrast, pediatricians made erroneous evaluations in 73% and 95% of cases, respectively. Obstetricians and gynecologists demonstrated a high degree of inaccuracy in their assessments, with a misjudgment occurring in 69% and 91% of cases, respectively. In contrast, the nonmedical participants exhibited a misjudgment rate of 50% and 76%, respectively.[6] The current results demonstrate the unreliability of the criteria to be used intuitively not only by the nonmedical professional group but also by physicians. The risk increases especially in images corresponding to the postpubertal period.

In the course of our investigation, we discovered that in five cases, the opinion of the police or police experts on age determination was sought. One of the limitations of our retrospective study is that very few of the case files contained the opinions of different experts. Despite this, in all the relevant files, our results were contrary to the opinions presented in the police reports. In all these cases, it was observed that the police experts determined the age of 16 or 17 instead of a specific age range. It is acknowledged that even physicians who have undergone rigorous clinical anatomy training and have examined a significant number of children during both their undergraduate and specialty training can make erroneous assessments. However, in the absence of a reliable source of information from a nonmedically trained professional group, age determination from digital data is likely to be no more than an assumption. It is important to note that this approach may result in significant errors, particularly among those without a medical background. Furthermore, the opinions of experts lacking adequate training on this issue could potentially lead to crucial legal misjudgements.

While artificial intelligence is employed in forensic medicine for the purposes of age and gender determination, it is also being utilized for the creation of so-called “deepfake” images. Recently, with the use of artificial intelligence, the faces of different people have appeared with “deepfake” face dressing. With this in mind, pornographic image evaluation should be done first after distinguishing whether the image is the product of an artificial intelligence tool or not.[35,36]

Sharing sexual photos among children and adolescents under the age of 18 of secondary school age is very common today. In one study, it was found that 7% of students sent sexually explicit photos of themselves one or more times, and no significant differences were observed between genders.[37] In our investigation, we discovered that 3% of the images were produced and uploaded to online platforms by the victim himself/herself. It is imperative that online service providers take measures to address the issue of child harassment, whether it occurs via instant messaging or online calls. They must implement effective solutions to mitigate these risks.[37,38] It is hypothesized that the act of sharing such images can be defined as the production of pornographic content, which may potentially lead to instances of bullying. In light of the methods employed to obtain the records in question, it is imperative to approach the matter with caution, taking into account the potential psychological impact on the children in question. It is

important to note that the failure to prosecute criminal acts will inevitably lead to an increase in such cases.

The study revealed that 69.1% of the images were shared for sexual purposes, 3.2% for joking purposes, and the purpose of sharing for 27.7% of the images could not be determined. The cases in which the purpose of sharing could not be determined consisted of images of women wearing miniskirts, bikinis, tights, or other clothes in daily life; images of men and women taken for nudism; a video of a 3- to 4-year-old boy taking a bath; and images of boys being bathed by their mothers taken from films. Although sharing such images of others may suggest a sexual purpose, it is assessed in the indeterminate group in our study as there is no definitive information.

Another striking point in our study is that some of the images sent to us within the scope of cybercrime consist of inappropriate joking posts. To illustrate, the content of some of these images is as follows: (i) video of a young naked boy crying after his penis is pecked and bitten by a cock, (ii) video of a baby goat trying to lick a little boy's penis and the boy crying: as the baby goat sucks it like a teat, hitting his groin with its head, the boy suffers and cries, and this is repeated many times, (iii) the act of placing glasses on the glans of a male infant, with the intention of creating the illusion of a human face, and (iv) a video of an unidentified person writing numbers from 1 to 9 on the buttocks of a baby boy lying face down with no clothes on his lower body and using these writings as a key to make a transaction with a bank card, revealing the money on the lower part of the child's body and trying to create the impression of withdrawing money from an ATM. Although it is assumed that they are not sent directly for the purpose of sexual gratification, a study conducted on the sharing of images without regard for children's privacy indicates that such images are frequently shared by families, thereby creating an opportunity for pedophiles to exploit children.[39] Furthermore, there is a possibility that these images may be utilized on pornographic websites.[40] In addition, when the statements and ages of the suspects were evaluated in the analyzed reports, it was observed that approximately half of them were under the age of 18, and those who posted inappropriate content for joking purposes stated that they did this with the perception of a simple Internet surfing without considering the possibility that their actions could be related to sexual abuse of the child.

In the course of our investigation, we observed that 2.9% of the images were accompanied by an animal. Zoophilia can be defined as an impulse disorder characterized by an attraction to animals as sexual objects. The study revealed the presence of video footage depicting animals, including chickens, goats, and donkeys, being utilized for sexual purposes by children below the age of 18. These images were captured in settings that resembled farm environments. It has been posited in the existing literature that pets or farm animals may be involved in cases of childhood zoophilia, a hypothesis that was corroborated by our own findings.[41,42] In the literature, cases of zoophilia have been shown to be associated with paedophilia and other sexual offense tendencies.[43] It is therefore hypothesized that the identification of these cases will facilitate the prevention of numerous issues, including child abuse, in the long term.

Conclusions

Age determination from digital images, which is one of the new topics that entered forensic medical practice with the widespread use of the Internet, still contains problems that have not been resolved sufficiently.

The primary challenge in image-based age determination, worldwide, is the presence of cases in the postpubertal period and the process of age determination by applying the age criterion of 18 years in general. It is imperative that new methods and technologies be enhanced to ensure accurate age determination from image recordings. Nevertheless, given that an error of ± 1 in evaluations conducted between the ages of 12 and 18 in diverse cases may result in victimization, it is imperative to utilize methodologies that align with the societal context in which the expert witness operates, particularly with regard to precise age determination. Furthermore, it is recommended to employ multiple methods, if feasible, to corroborate the findings.

As seen in our study, the decisions made by intelligent systems are not yet at the desired level of precision. While the fact that most of the images do not fully include the human body and the inability to perform a physical examination by a physician significantly affects the decision-making processes and success rates of human experts, it is inevitable that these limitations will also affect intelligent systems.

The reasons why intelligent systems mispredict children are complex and multifaceted. This can be attributed to many factors, including the utilization of restricted or incomplete data sets in AI systems, genetic and sociocultural discrepancies, and inconsistencies between disparate societies. It is evident that greater care and attention must be devoted to the design and training of these systems.

Another conclusion of our study is that, given the current limitations of intelligent systems in solving this

problem, it is advisable to select experts in such forensic cases from among forensic medicine physicians who are trained in human anatomy and physiology and have experience in age determination. Otherwise, there is a risk of individuals being subjected to unwarranted punishment on the basis of an expert report that is not supported by empirical evidence and is instead based on the personal professional experience and subjective opinions.

Although the principal objective of smart technologies, which are frequently utilized by judicial authorities in a multitude of capacities, including age determination, is to guarantee justice by identifying criminal activities and perpetrators, the erroneous outcomes of these instruments can potentially engender significant adverse consequences. In order to circumvent these missteps, it is proposed that international guidelines be established to guarantee that comprehensive preliminary studies are conducted prior to the implementation of these technologies. It is also recommended that technologies should be transparent and auditable, with independent supervisory boards if necessary, and that all processes should be bounded by an ethical and legal framework.

Erroneous age determination, whether by artificial intelligence systems or by experts, may have individual and social consequences. To illustrate, if a report is issued falsely stating that an adult image is a child, the suspect may face an unfair accusation and may may consequently receive an unjustified punishment. In addition, there is a serious negative reaction against people who commit child abuse offenses in the society. Such misunderstandings may result in a loss of reputation and trust, which could have a detrimental impact on the family and business life of individuals. In the opposite scenario, if the age of a child is incorrectly stated as an adult, it may result in children not being protected from such offenses. In both instances, this leads to a loss of trust in the legal system.

Despite the absence of a definitive methodology for age determination evaluations based on digital images, in this critical issue, which can have serious and perhaps irreversible consequences in case of a mistake, it is thought that the evaluation of different body parts together, the joint evaluation of intelligent systems and physician experts with a multidisciplinary understanding is one of the solutions.

Finally, as the data were obtained from a single center, the study's generalizability to the wider population is limited. Therefore, the findings should be corroborated by other multicenter studies.

Limitations: Since the study was single-centered and its structure was retrospective, it was considered as a limitation since only limited previously recorded findings were used in the study. Although our study focused more on investigation materials, some details about the suspects could not be included as some of the files in the study were still in the prosecution process and it was impossible to collect information about the suspects. In addition, since there were not enough different expert reports in the file contents, a clear evaluation could not be performed regarding the differences in expert opinions.

Ethical approval

The study was approved by the Non-Interventional Clinical Research Ethics Committee of Karabuk University on February 27, 2023, and was assigned the number 2023/1269.

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Conflicts of interest

There are no conflicts of interest.

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