ISSN: 2717-8161 RESEARCH ARTICLE

New Trends in Medicine Sciences

New Trend Med Sci 2020; 1(2): 106-117. https://dergipark.org.tr/tr/pub/ntms

Determination of Developmental Dysplasia of the Hip Using Artificial Neural Networks (ANN) on Ultrasound Viewing According to Graf's Method

Kadri Yıldız[1*], Vahit Yıldız[2]

[1]Department of Orthopaedia and Traumatology, Faculty of Medicine, Kafkas University, Kars, Turkey
[2]Department of Orthopaedia and Traumatology, Faculty of Medicine, Adnan Menderes University, Aydın, Turkey

Article History
Received 16 Aug 2020
Accepted 09 Sep 2020
Published Online 30 Sep 2020

[*]***Corresponding Author***
Dr Kadri Yıldız
Department of Orthopedia and Traumatology,
Faculty of Medicine,
Kafkas Univeristy, Kars, Turkey,
Phone: +90 538 545 0559
E-mail: drkadri1980@hotmail.com
ORCID: https://orcid.org//0000-0002-8164-7687

Abstract: Developmental dysplasia of the hip (DDH) is a preventable disorder. Hip ultrasound is the best choice for the early detection of hip deformity. But, because of the multitude of out-patient clinics, sometimes mixing may be occurred. We organize a study to determine the usable capability of Artificial Neural Networks (ANN) for follow up of hip ultrasonography according to the Graf's US method. 135 cases with hip ultrasonography evaluation have been obtained from the study group. Alpha and beta angles were measured according to the Graf's US method. Two groups were determined according to alpha and beta angles, gender, and the Graf's US classification. Measurements were done by a radiologist that 25-year experienced. The databases were loaded to the software. 18 samples for the input data and target data were selected among 135 cases. The samples were used for training the neural network. The target date was arranged for 3 types (Type I, II, and III). Resilient Backpropagation" training function as 87.4%. The coefficient of determination (R-Squared) and accuracy values were 100% in most cases. And Polak-Ribiére Conjugate Gradient training function as 83.0%. We consider that using artificial intelligence to follow these USG records may provide easier follow-up. Thus, possible mixing problems can be avoided.
Keywords: Developmental Dysplasia of the Hip, Graf's US Method, Artificial Neural Networks.

1. Introduction

Developmental dysplasia of the hip (DDH) is one of the common orthopedic diseases. It is seen nearly in 1/1000 born, the female/male ratio is 6/1. The DDH is a dynamic musculoskeletal disease, and the treatment is easier in the earlier months. Some musculoskeletal diseases may be risks factor for the DDH as torticollis, congenital club foot, metatarsus adductus.

Pregnancy period, type of birth, first birth, prematurity, family history, gender is etiologic factors for DDH. Ultrasound (US) viewing according to Graf's method is the one of used tool for diagnosis of the DDH because of its advantages as absent of radiation risks and early diagnosis (1-3).

The Graf's classification includes several major types

Cite this article as: Yıldız K and Yıldız V. Determination of Developmental Dysplasia of the Hip Using Artificial Neural Networks (ANN) on Ultrasound Viewing According to Graf's Method, *New Trend Med Sci* **2020**; 1(2): 106-117.

that have subdivided. The types are classified by angle measurements and morphological aspects (Table 1) (4). Neural networks can be used as a classification system to determine malformed classes where the definition of an undesirable characteristic would not change. The network would be expected to perform the same classification repeatedly (5). Receiver Operating Characteristics (ROC) graphs are useful for organizing classifiers and visualizing performance. ROC graphs are used in medical decision making commonly. In recent years it has been used increasingly in machine learning and data mining research. Although ROC graphs are considered as simple, some common misconceptions and pitfalls occur in some studies (6).
This research aims to determine the best Artificial Neural Networks (ANN) structure for classification to be used in the diagnosis of developmental dysplasia of the hip classes using alpha and beta angles obtained from US and to test the most successful network on the cases of the orthopedic clinic.

2. Material and Methods

This research has been approved by the IRB of the authors' affiliated institutions. Ethics approval was obtained for this study. The data of 135 cases have been obtained from the orthopedic clinic of our hospital by using ultrasonography. Measurement of alpha and beta angles was done according to the Graf's US method.
The data were divided into 2 groups according to which side (left or right) that have developmental dysplasia of the hip. Each group has been treated separately and has its information about alpha and beta angles, gender, and the Graf's US classification.
In the general primer care of a newborn, hip ultrasounds according to the Graf's classification were assessed. The alpha and beta angle measurements were made by a radiologist that has worked in our university hospital. The alpha angle is drawn between the acetabular roof and the vertical cortex of the ilium. It reflects the development of the bony acetabular roof. The beta angle is drawn between the vertical cortex of the ilium and the triangular labral fibrocartilage. It measures the cartilaginous coverage over the femoral head. Alpha and beta angles are continuous measurements that are determined during ultrasound hip imaging. The angles are classified for hip type (Ia, Ib, IIa, IIb, IIc, III, IV, or D) (7).
The data was organized using tabulation software. 18 samples for the input data and target data were selected among 135 cases. The samples were regarded to be determinant for training the neural network. There were not any cases in some hip dislocation classes. In some classes, there were a few cases. For this reason, the target data was arranged for 3 types (Type I, II, and III). The artificial neural network (ANN) for the classification of hip dislocation was established, trained, and tested in Mathworks Matlab R2015a software. For these purposes, a script was coded, following the steps shown in Listing 1.

The script runs 27 combinations of 3 different neuron numbers (3, 6, 10) in the hidden layer and 9 different training functions. The training functions are listed in Table 2. Half of the input values were used for training, a quarter for validation, and the rest for testing. For each combination, the script loops at most 20 times to reach the desired performance values. Among those networks, the network with the best performance value was saved to get the outputs. The coefficient of determination (R-Squared) of the network was calculated using targets across outputs.
The best network out of 27 combinations was compared to the others and the network with the highest R-Squared value was used on all of 135 cases. The confusion matrix of the network was conducted using outputs and targets using the 0.5 thresholds.
The accuracy of the networks was calculated with the formula:

$$Accuracy = \frac{TP+TN}{P+N} \quad [1].$$

where TP is true positives, TN is true negatives, P is several positives and N is the number of negatives. ANN diagram for classification with 10 neurons in the hidden layer is shown in Figure 1.

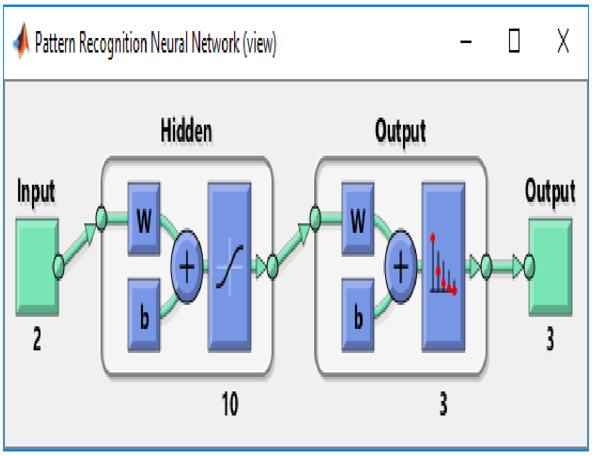


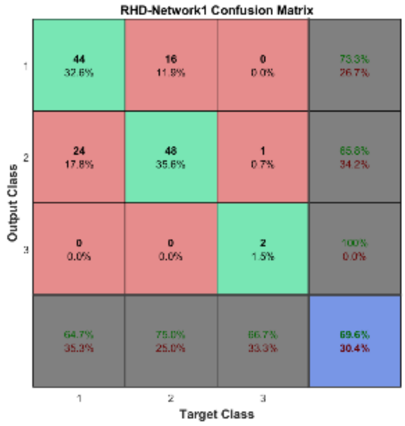
Figure 1: Demonstration of pattern recognition neural network.

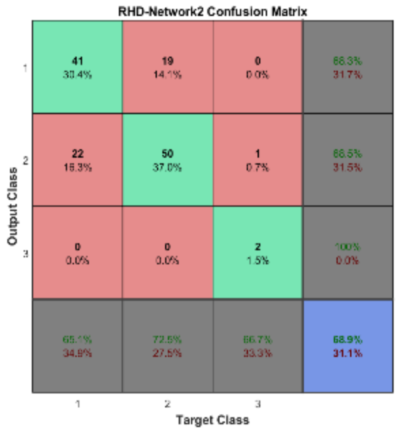
3. Results

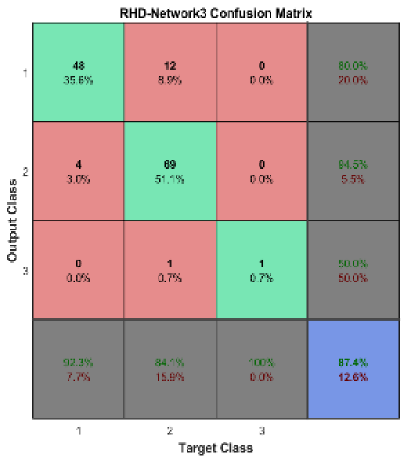
The script firstly was run for the right hip. Networks with 10 neurons in the hidden layer had the highest coefficient of determination (R-Squared) values and most of them had 100% accuracy while training. The highest R-Squared value was measured for the network with 10 neurons in the hidden layer, "One Step Secant" and "Variable Learning Rate Backpropagation" training functions. However, when the networks were tested for all the samples, the highest accuracy was found with the network with 3 neurons in the hidden layer, and the "Resilient Backpropagation" training function as 87.4% (Listing 2, Figures 2).
Lastly, the script was run for hip dislocation on the left. Most of the networks had 100% of the coefficient of

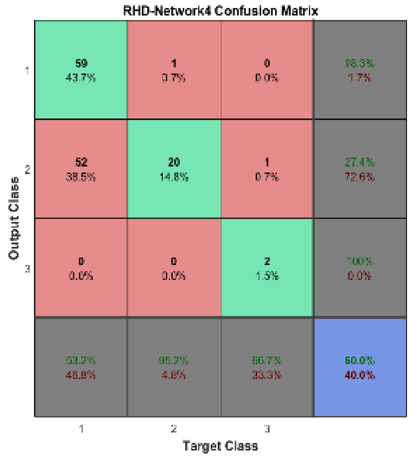
determination (R-Squared) values and most of them had 100% accuracy while training.

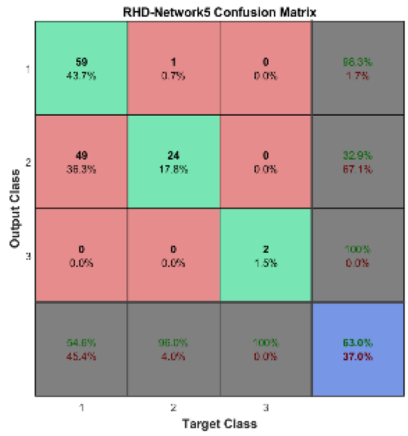
However, when the networks were tested for all the samples, the highest accuracy was found with the network with 10 neurons in the hidden layer and "Polak-Ribiére Conjugate Gradient" training function as 83.0% (Listing 3 and Figures 3).

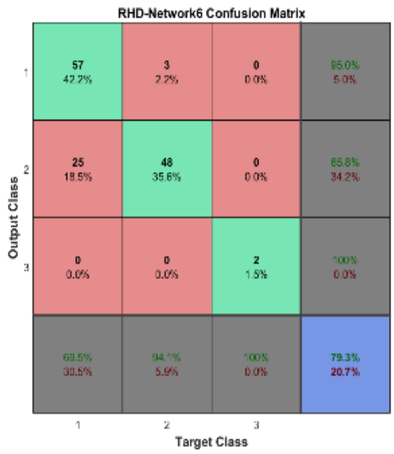


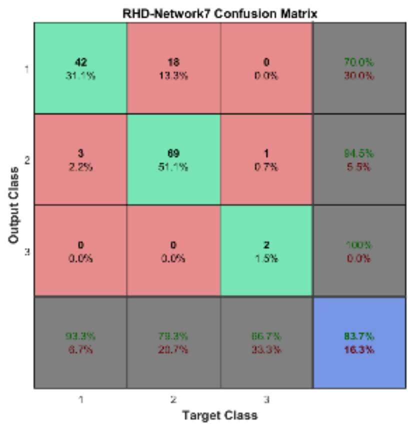


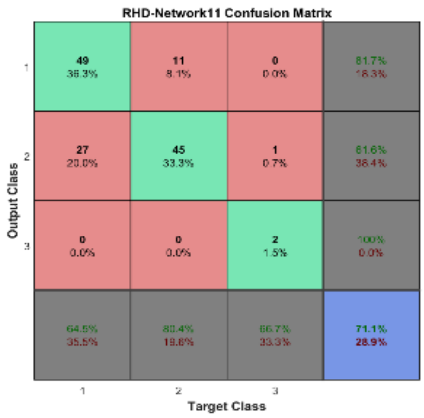


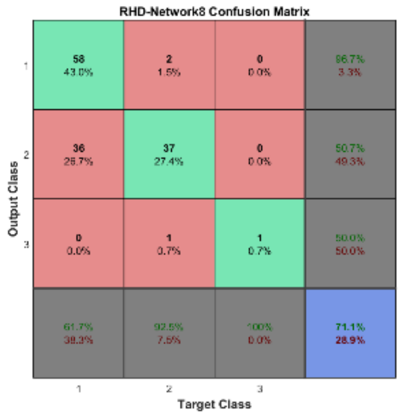


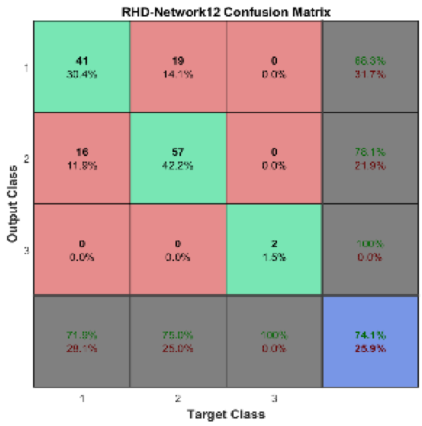


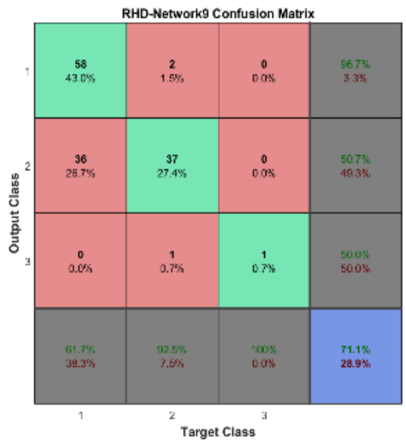


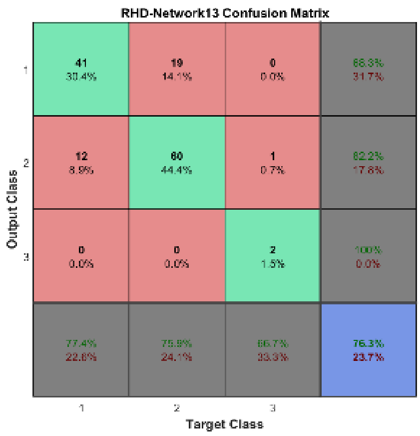

RHD-Network7 Confusion Matrix
Output Class
Target Class

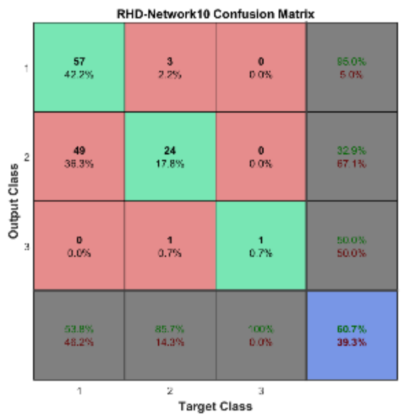

RHD-Network11 Confusion Matrix
Output Class
Target Class

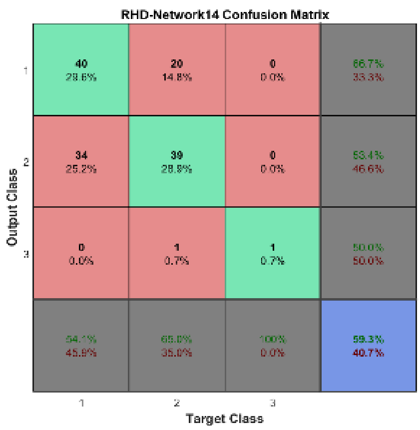

RHD-Network8 Confusion Matrix
Output Class
Target Class

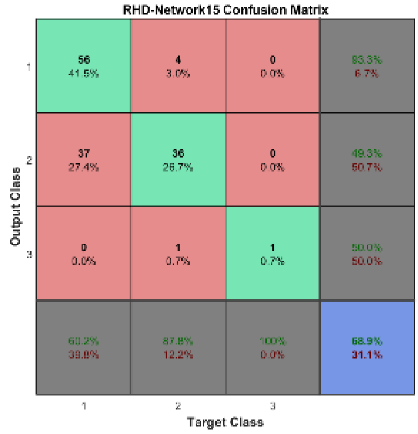

RHD-Network12 Confusion Matrix
Output Class
Target Class

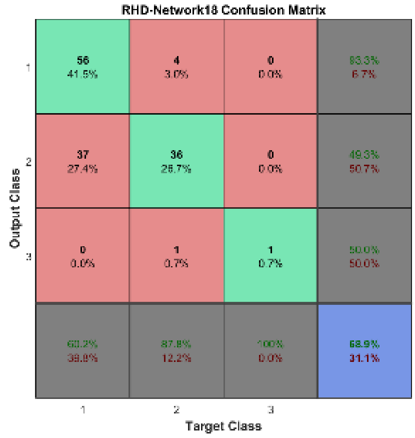

RHD-Network9 Confusion Matrix
Output Class
Target Class

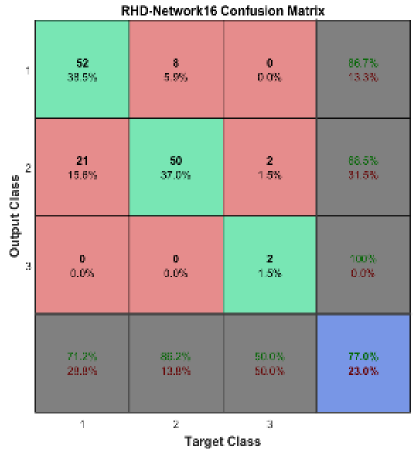

RHD-Network13 Confusion Matrix
Output Class
Target Class

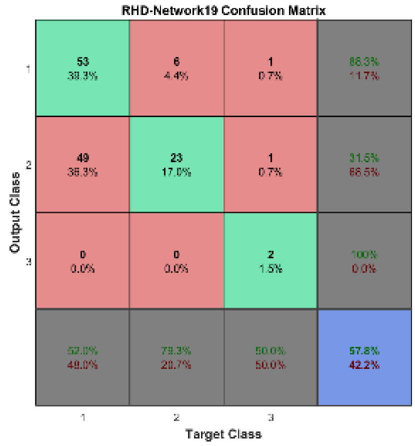

RHD-Network10 Confusion Matrix
Output Class
Target Class

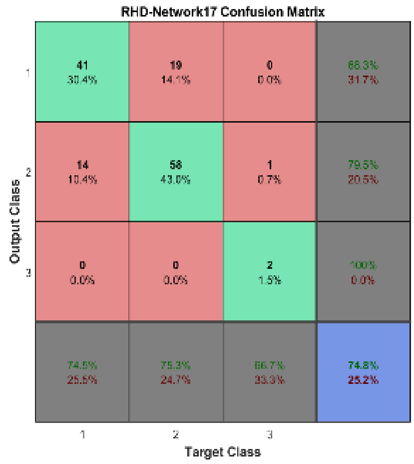

RHD-Network14 Confusion Matrix
Output Class
Target Class

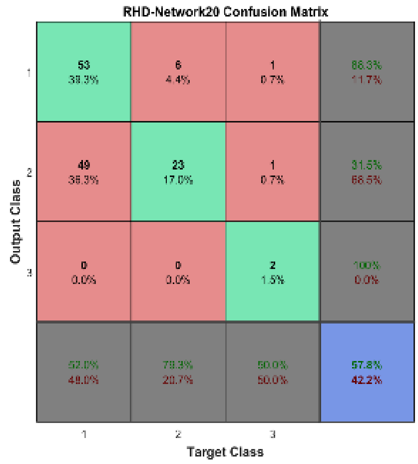

RHD-Network15 Confusion Matrix
Output Class
Target Class

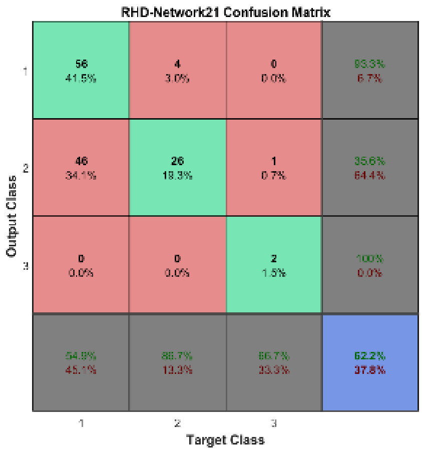

RHD-Network18 Confusion Matrix
Output Class
Target Class

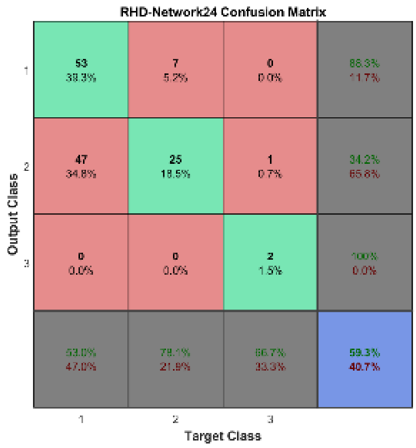

RHD-Network16 Confusion Matrix
Output Class
Target Class

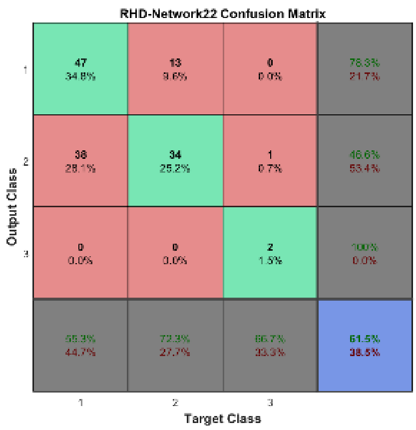

RHD-Network19 Confusion Matrix
Output Class
Target Class

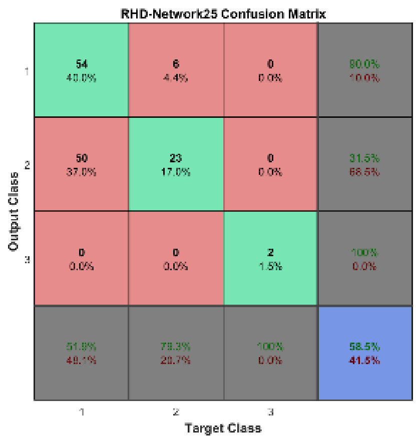

RHD-Network17 Confusion Matrix
Output Class
Target Class

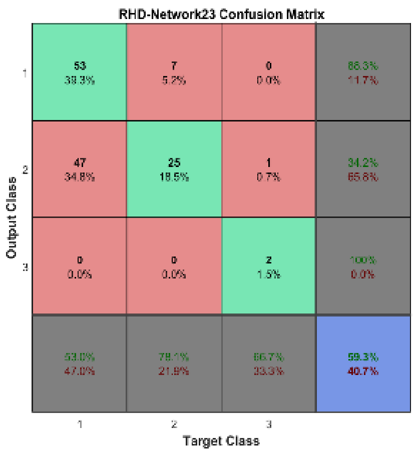

RHD-Network20 Confusion Matrix
Output Class
Target Class


RHD-Network21 Confusion Matrix
56 41.5%
4 3.0%
0 0.0%
93.3% 6.7%
46 34.1%
26 19.3%
1 0.7%
35.6% 64.4%
0 0.0%
0 0.0%
2 1.5%
100% 0.0%
54.9% 45.1%
86.7% 13.3%
66.7% 33.3%
62.2% 37.8%
Output Class
Target Class


RHD-Network24 Confusion Matrix
53 39.3%
7 5.2%
0 0.0%
88.3% 11.7%
47 34.8%
25 18.5%
1 0.7%
34.2% 65.8%
0 0.0%
0 0.0%
2 1.5%
100% 0.0%
53.0% 47.0%
78.1% 21.9%
66.7% 33.3%
59.3% 40.7%
Output Class
Target Class


RHD-Network22 Confusion Matrix
47 34.8%
13 9.6%
0 0.0%
78.3% 21.7%
38 28.1%
34 25.2%
1 0.7%
46.6% 53.4%
0 0.0%
0 0.0%
2 1.5%
100% 0.0%
55.3% 44.7%
72.3% 27.7%
66.7% 33.3%
61.5% 38.5%
Output Class
Target Class


RHD-Network25 Confusion Matrix
54 40.0%
6 4.4%
0 0.0%
90.0% 10.0%
50 37.0%
23 17.0%
0 0.0%
31.5% 68.5%
0 0.0%
0 0.0%
2 1.5%
100% 0.0%
51.9% 48.1%
79.3% 20.7%
100% 0.0%
58.5% 41.5%
Output Class
Target Class


RHD-Network23 Confusion Matrix
53 39.3%
7 5.2%
0 0.0%
88.3% 11.7%
47 34.8%
25 18.5%
1 0.7%
34.2% 65.8%
0 0.0%
0 0.0%
2 1.5%
100% 0.0%
53.0% 47.0%
78.1% 21.9%
66.7% 33.3%
59.3% 40.7%
Output Class
Target Class

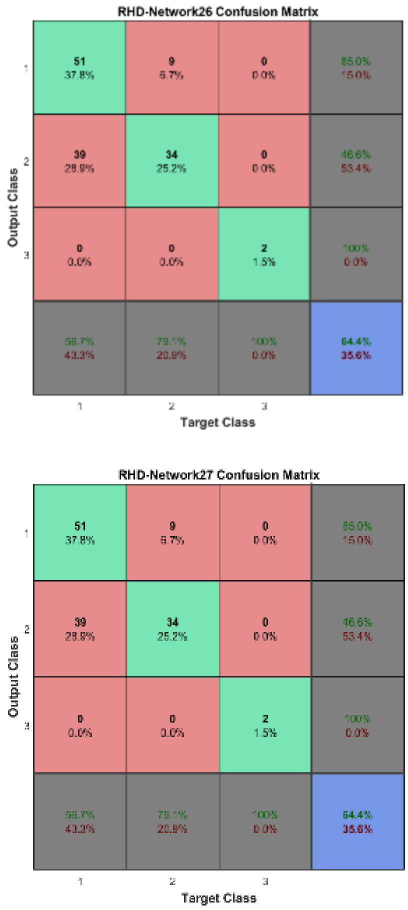
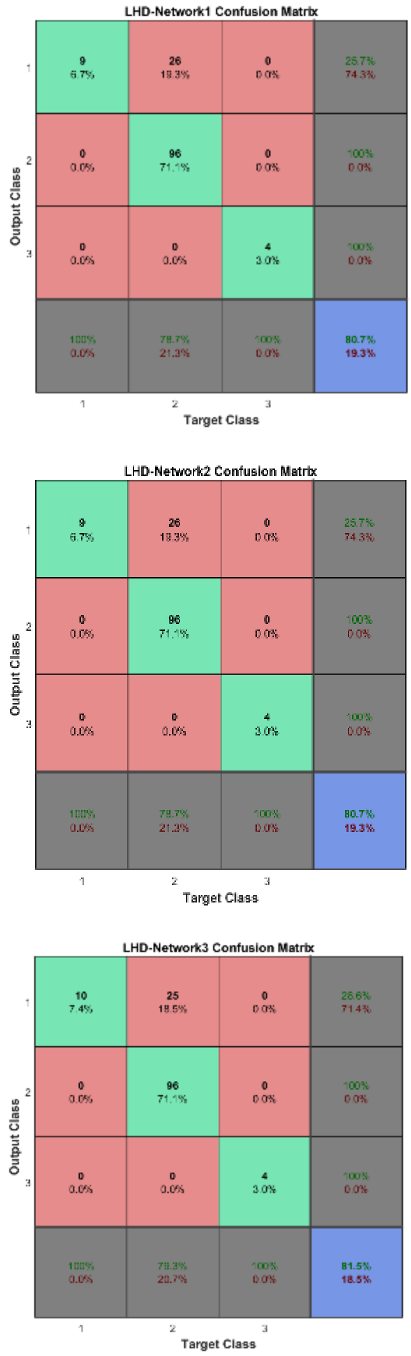
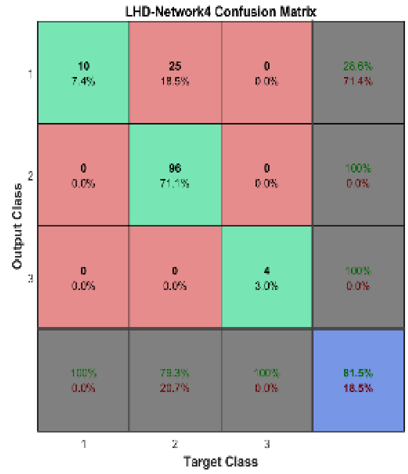
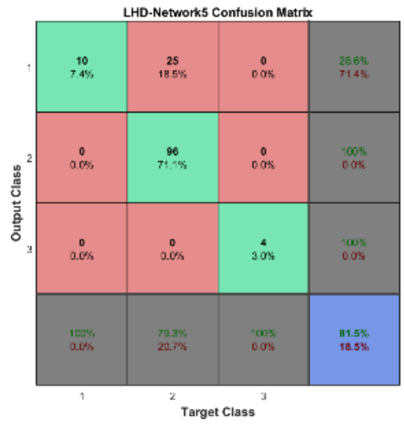
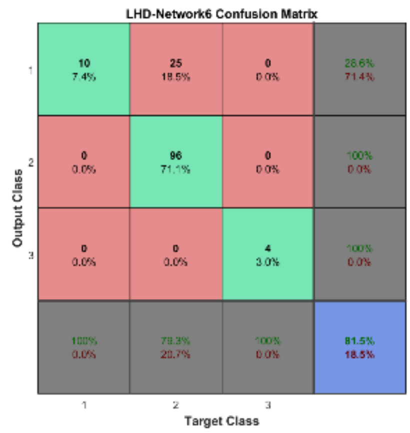


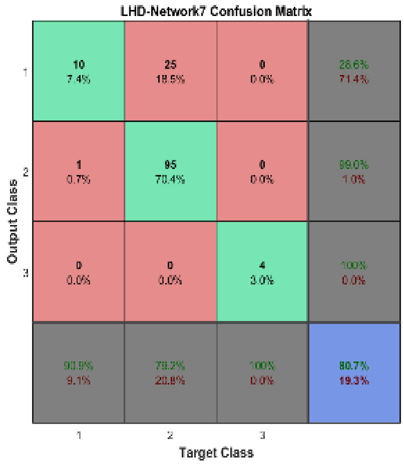
Figure 2: RHD Network Confusion Matrix (Network confusion matrix for right hip dysplasia disease.

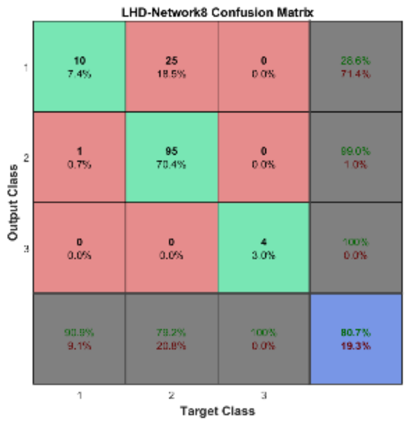


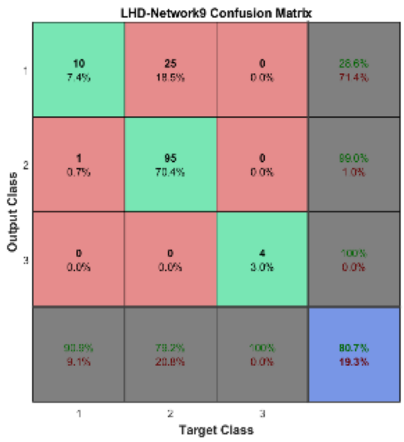

LHD-Network4 Confusion Matrix
10 7.4%
25 18.5%
0 0.0%
28.6% 71.4%
0 0.0%
96 71.1%
0 0.0%
100% 0.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
100% 0.0%
79.3% 20.7%
100% 0.0%
81.5% 18.5%
Output Class
1
2
3
Target Class

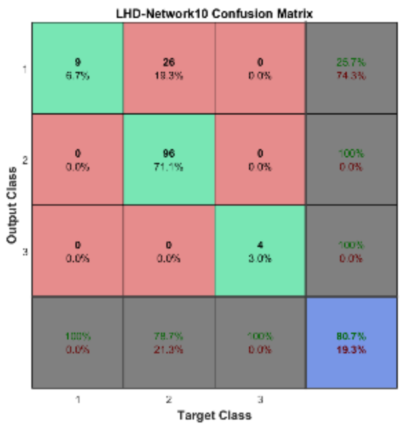

LHD-Network5 Confusion Matrix
10 7.4%
25 18.5%
0 0.0%
28.6% 71.4%
0 0.0%
96 71.1%
0 0.0%
100% 0.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
100% 0.0%
79.3% 20.7%
100% 0.0%
81.5% 18.5%
Output Class
1
2
3
Target Class

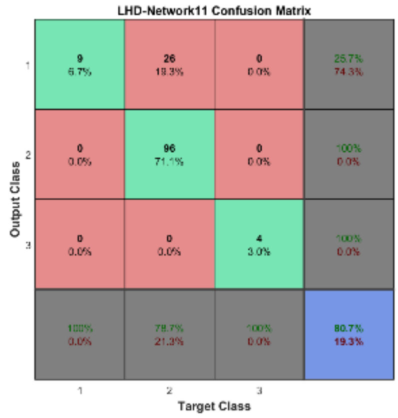

LHD-Network6 Confusion Matrix
10 7.4%
25 18.5%
0 0.0%
28.6% 71.4%
0 0.0%
96 71.1%
0 0.0%
100% 0.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
100% 0.0%
79.3% 20.7%
100% 0.0%
81.5% 18.5%
Output Class
1
2
3
Target Class

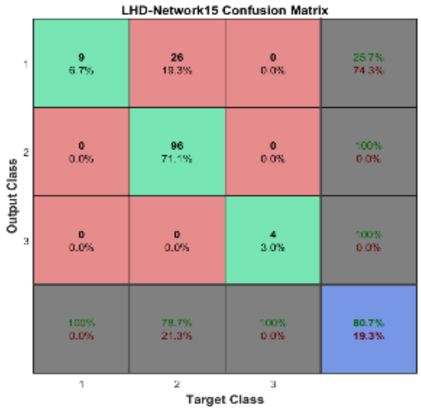

LHD-Network7 Confusion Matrix
10 7.4%
25 18.5%
0 0.0%
28.6% 71.4%
1 0.7%
95 70.4%
0 0.0%
99.0% 1.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
90.9% 9.1%
79.2% 20.8%
100% 0.0%
80.7% 19.3%
Output Class
1
2
3
Target Class

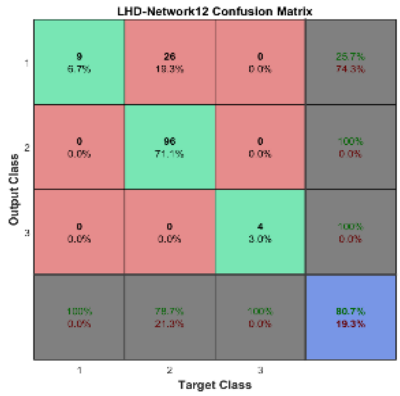

LHD-Network8 Confusion Matrix
10 7.4%
25 18.5%
0 0.0%
28.6% 71.4%
1 0.7%
95 70.4%
0 0.0%
99.0% 1.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
90.9% 9.1%
79.2% 20.8%
100% 0.0%
80.7% 19.3%
Output Class
1
2
3
Target Class

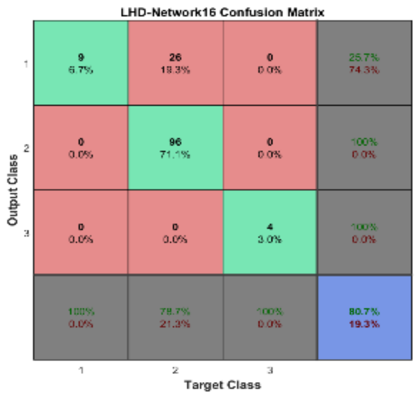

LHD-Network9 Confusion Matrix
10 7.4%
25 18.5%
0 0.0%
28.6% 71.4%
1 0.7%
95 70.4%
0 0.0%
99.0% 1.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
90.9% 9.1%
79.2% 20.8%
100% 0.0%
80.7% 19.3%
Output Class
1
2
3
Target Class

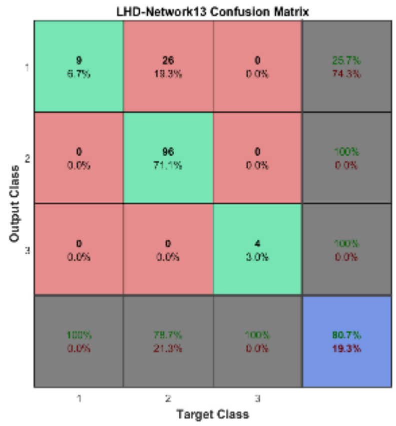

LHD-Network10 Confusion Matrix
9 6.7%
26 19.3%
0 0.0%
25.7% 74.3%
0 0.0%
96 71.1%
0 0.0%
100% 0.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
100% 0.0%
78.7% 21.3%
100% 0.0%
80.7% 19.3%
Output Class
1
2
3
Target Class

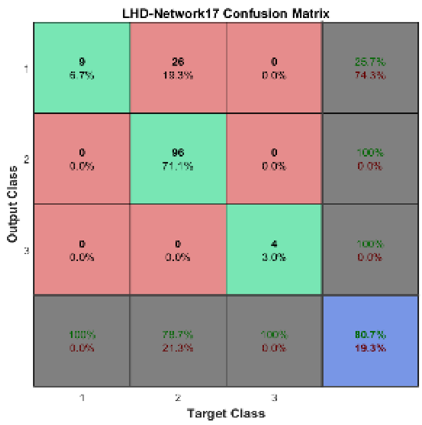

LHD-Network11 Confusion Matrix
Output Class
Target Class

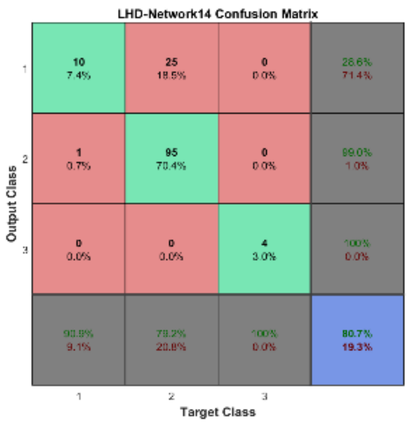

LHD-Network15 Confusion Matrix
Output Class
Target Class

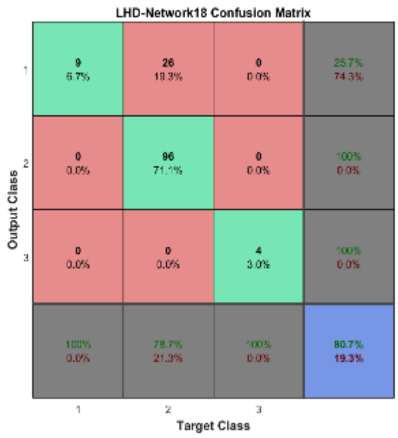

LHD-Network12 Confusion Matrix
Output Class
Target Class

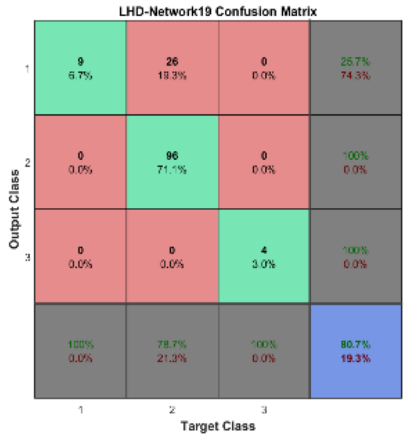

LHD-Network16 Confusion Matrix
Output Class
Target Class

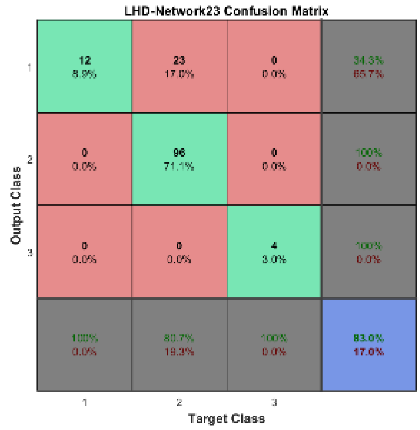

LHD-Network13 Confusion Matrix
Output Class
Target Class

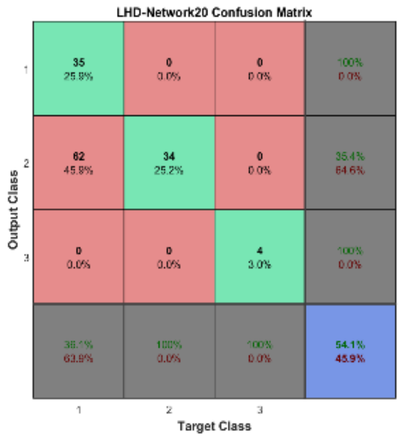

LHD-Network17 Confusion Matrix
Output Class
Target Class

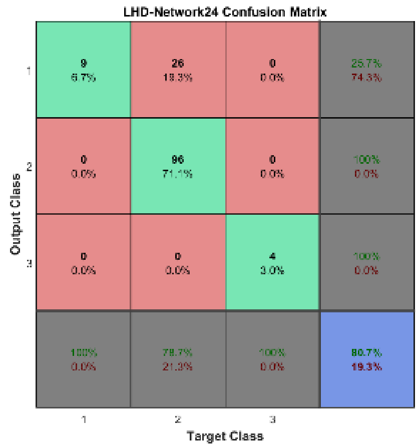

LHD-Network14 Confusion Matrix
Output Class
Target Class

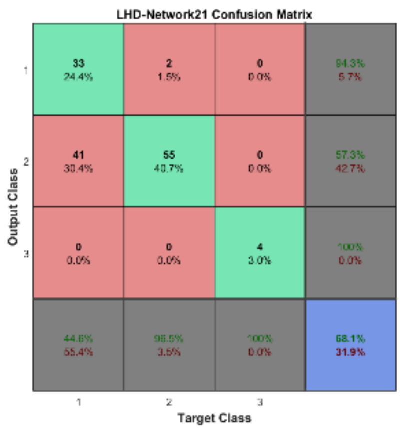

LHD-Network18 Confusion Matrix
Output Class
Target Class

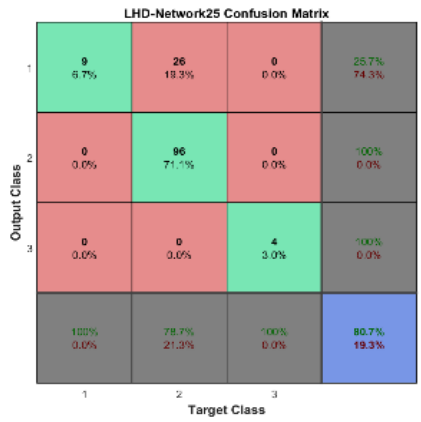

LHD-Network19 Confusion Matrix
9 6.7%
26 19.3%
0 0.0%
25.7% 74.3%
0 0.0%
96 71.1%
0 0.0%
100% 0.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
100% 0.0%
78.7% 21.3%
100% 0.0%
80.7% 19.3%
Output Class
Target Class

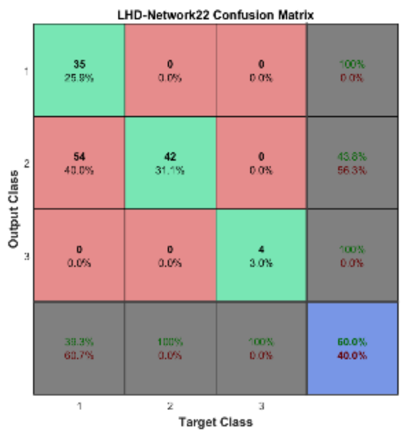

LHD-Network23 Confusion Matrix
12 8.9%
23 17.0%
0 0.0%
34.3% 65.7%
0 0.0%
96 71.1%
0 0.0%
100% 0.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
100% 0.0%
80.7% 19.3%
100% 0.0%
83.0% 17.0%
Output Class
Target Class

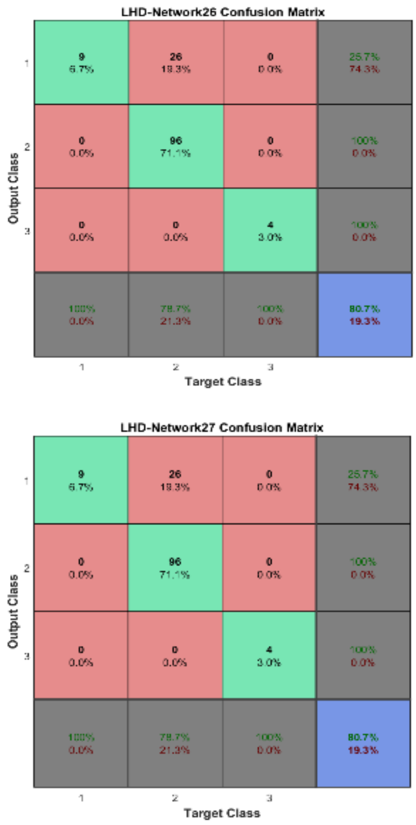

LHD-Network20 Confusion Matrix
35 25.9%
0 0.0%
0 0.0%
100% 0.0%
62 45.9%
34 25.2%
0 0.0%
35.4% 64.6%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
36.1% 63.9%
100% 0.0%
100% 0.0%
54.1% 45.9%
Output Class
Target Class


LHD-Network24 Confusion Matrix
9 6.7%
26 19.3%
0 0.0%
25.7% 74.3%
0 0.0%
96 71.1%
0 0.0%
100% 0.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
100% 0.0%
78.7% 21.3%
100% 0.0%
80.7% 19.3%
Output Class
Target Class


LHD-Network21 Confusion Matrix
33 24.4%
2 1.5%
0 0.0%
94.3% 5.7%
41 30.4%
55 40.7%
0 0.0%
57.3% 42.7%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
44.6% 55.4%
96.5% 3.5%
100% 0.0%
68.1% 31.9%
Output Class
Target Class


LHD-Network25 Confusion Matrix
9 6.7%
26 19.3%
0 0.0%
25.7% 74.3%
0 0.0%
96 71.1%
0 0.0%
100% 0.0%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
100% 0.0%
78.7% 21.3%
100% 0.0%
80.7% 19.3%
Output Class
Target Class


LHD-Network22 Confusion Matrix
35 25.9%
0 0.0%
0 0.0%
100% 0.0%
54 40.0%
42 31.1%
0 0.0%
43.8% 56.3%
0 0.0%
0 0.0%
4 3.0%
100% 0.0%
39.3% 60.7%
100% 0.0%
100% 0.0%
60.0% 40.0%
Output Class
Target Class



Figures 3: LHD Network Confusion Matrix (Network confusion matrix for left hip dysplasia disease.

4. Discussion

Developmental dysplasia of the hip (DDH) is a pediatric musculoskeletal disorder (8). The reported incidence of DDH is between 1 and 34 per 1000 newborns (9, 10). In Europe, it is between 3% and 13%, real dysplasia as between 1% and 3% (11, 12). In 1988, Huang reported the incidence of DDH was 2,7/1000 in Taiwan. The incidence of a one-year follow-up was 1.2/1000 (13). In our country, the rate is between 0.4/1000 and 1.7/1000 as a wide range (14-24).

Ultrasonography was introduced to orthopedic trials in the 1980s. This method has been assured to evaluate the infant's hip structure. The Graf's classification has gained popularity due to its early detection and accuracy features (7,25). Ultrasound screening for DDH is has become more effective at detecting the disease. National Health Services (NHS) from the United Kingdom's Newborn and Infant Physical Examination (NIPE) Programme advises hip ultrasound screening within 2-6 weeks.

Lusier screened 1683 newborns during their study period (25). They declared that later than 28 days after birth does not increase surgery rates and it might reduce clinical visits counts. They recommended a cut-off day like 28 days. Also, they predicted decreasing of parental stress, lesser the number of ultrasound studies, cost-sensitive screening programs. Also, this condition reduces the multitude of pediatric and orthopedic clinics, the beneficial use of medical resources.

Ultrasonographic early detection of DDH by the Graf's US method is recommended for reducing the need for surgery and comorbidities due to operations (25). Roovers found that earlier screenings could provide an early diagnosis of abnormal hips (26). However, follow-up of frequent US scans can be a problem for orthopedic surgeons and radiologists during intensive policlinic service. Especially during serial and personal follow-up of the patients for the Graf's US scans, mixing and non-tracking problems may arise. In our country, almost 100 patients are examined daily in orthopedic policlinics.

5. Conclusions

In the outpatient clinics, we emphasize that using artificial intelligence to follow these US records may provide more correct follow-up. The mixing can be avoided in this way.

Conflict of interest statement

The authors declare that they have no conflict of interest.

Financial Support

There is no funding source.

Ethical approval

Ethics approval was obtained for this study.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Acknowledgment

Thank you to Sefa Altıkat for the support in this study.

References

1. Graf R. Hip Sonography. Diagnosis and management of infant hip dysplasia. Berlin, Springer **2006**. p. 1-87.
2. Omeroglu H. Ultrasonographic Graf type 2a hip needs more consideration in newborn girls. *J Chilp Orthop* **2013**; 7(2): 95-98.
3. Puhan MA, Woolacott N, Kleijinen J, Streurer J. Observational studies on ultrasound screening for developmental dysplasia of the hip in a newborns-a systematic review. *J Ultrasound Med* **2003**; 24(6): 377-82
4. Langer R. Ultrasonic investigation of the hip in newborns in the diagnosis of congenital hip dislocation: classification and results of a screening program, *Skeletal Radiol* **1987**; 16: 275-279
5. Taylor BJ. Methods and Procedures for the Verification and Validation of Artificial Neural Networks, Springer **2006**; p: 280
6. Fawcett T. An Introduction to ROC Analysis. *Pattern Recognition Letters* **2005**; 27(8): 861-874

7. Graf R. New possibilities for the diagnosis of congenital hip joint dislocation by ultrasonography. *J Pediatr Orthop* **1983**; 3(3): 354–359

8. Storer SK, Skaggs DL. Developmental dysplasia of the hip. *Am Fam Physician* **2006**; 15; 74(8): 1310-1316.

9. Tachdjian M. Congenital dysplasia of the hip. In: Tachdjian M, editor. Pediatric Orthopaedics. Philadelphia: W.B. Saunders. **1990**; p: 247-549

10. 10. Noordin S, Umer M, Hafeez K, Nawaz H. Developmental dysplasia of the hip. *Orthop Rev (Pavia)* **2010**; 23;2(2): e19.

11. Holen KJ, Terjesen T, Tegnander A, Bredland T, Saether OD, Eik-Nes SH. Ultrasound Screening for Hip Dysplasia in Newborns. *J Pediatr Orthop* **1994**; 14(5): 667-73.]

12. Rosendahl K, Markestad T, Lie RT. Developmental dysplasia of the hip. A population-based comparison of ultrasound and clinical findings. *Acta Paediatr* **1996**; 85(1):64-9.

13. Huang SC, Liu HC, Chen CF, Chen CL, Liu TK. Incidence of congenital dislocation of the hip in Chinese. *J Orthop Surg* **1988**; 5(3): 53-65

14. Dogruel H, Atalar H, Yavuz OY, Sayli U. Clinical examination versus ultrasonography in detecting developmental dysplasia of the hip. *Int Orthop* **2008**; 32(3): 415-9.

15. Duramaz A, Peker G, Arslan L, Bilgili MG, Erçin E, Kural C. Hip Ultrasonography in the Diagnosis of Developmental Dysplasia of the Hip: Bakırköy Experience. *Med Bull Haseki* **2014**; 52(2): 262-267

16. Cakir BC, Kibar AE, Cakir HT, Arhan E, Cansu A, Yakut HI. Screening of 300 Infants for Developmental Hip Dysplasia by Ultrasonography. *Turkey Children's Hospital Journal* **2009**; 3(2): 5-9.

17. Demirhan M, Shar C, Aydinok HC, Cakmak M, Coban A. Ultrasonography in the diagnosis of congenital hip dislocation. *Acta Orthop Traumatol Turc* **1994**; 28: 8-14

18. Oguz T, Ege A, Gungor S, Toppare M, Erdemtok N. The ultrasonographic evaluation of 1099 infants by Graf method. *Arthroplasty Arthroscopic Surgery* **1996**; 7: 64-66

19. Okur A, Nakışlar F, Karsan O, Alparslan B. The value of ultrasonographic examination in diagnosis and screening of congenital hip dislocation. *Acta Orthop Traumatol Turc* **1996**; 30: 107-112

20. Kose N, Omeroglu H, Ozyurt B. Our three-year experience in the ultrasonographic hip screening program in infants of three to four weeks. *Acta Orthop Traumatol Turc* **2006**; 40(4): 285-90.

21. Akman A, Korkmaz A, Aksoy MC, Yazici M, Yurdakok M, Tekinalp G. Evaluation of risk factors in developmental dysplasia of the hip: results of infantile hip ultrasonography. *Turk J Pediatr* **2007**; 49(3): 290-4.

22. Tosun HB, Bulut M, Karakurt L, Belhan O, Serbest S. Evaluation of hip ultrasonography results for developmental hip dysplasia screening. *Firat Med J* **2010**; 15(4): 178-183

23. Cekic B, Erdem-Toslak I, Sertkaya O. Incidence and follow-up outcomes of developmental hip dysplasia of newborns in the Western Mediterranean Region. *Turk J Pediatr* **2015**; 57(4): 353-358

24. Sahin F, Akturk A, Beyazova U. Screening for developmental dysplasia of the hip: results of a 7-year follow-up study. *Pediatr Int* **2004**; 46(2): 162-6.

25. Lussier EC, Sun YT, Chen HW, Chang TY, Chang CH. Ultrasound screening for developmental dysplasia of the hip after 4 weeks increases exam accuracy and decreases follow-up visits. *Pediatr Neonatol* **2019**; 60(3): 270-277.

26. Roovers EA, Boere-Boonekamp MM, Castelein RM, Zielhuis GA, Kerkhoff TH. Effectiveness of ultrasound screening for developmental dysplasia of the hip. *Arch Dis Child Fetal Neonatal Ed* **2005**; 90(1): 25-30.

Authors' ORCID
Kadri Yıldız
http://orcid.org/0000-0002-8164-7687
Vahit Yıldız
http://orcid.org/0000-0003-3639-0912

https://dergipark.org.tr/tr/pub/ntms